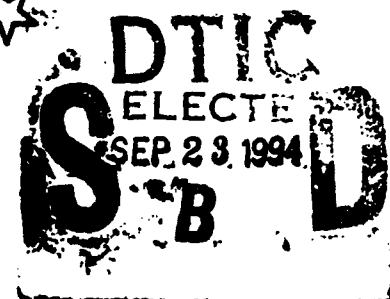


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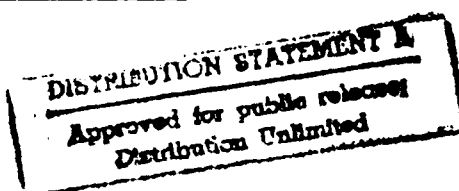


COHERENCE AND USABILITY
OF AN
ENVIRONMENTAL IMPACT STATEMENT

THESIS

Jill A. Easterly

AFIT/GEE/ENV/94S-07



DEPARTMENT OF THE AIR FORCE

Air University

Air Force Institute of Technology

Wright Patterson Air Force Base, Ohio

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AFIT/GEE/ENV/94S-07

EFFECTS OF COHESION
ON
COHERENCE AND USABILITY
OF AN
ENVIRONMENTAL IMPACT STATEMENT

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Environmental Management

Jill A. Easterly, B.S.

September 1994

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Jill A. Easterly

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Abstract

The purpose of this research effort was to investigate the application of certain principles of effective communication to improve the comprehension, and ultimately the usability, of an Environmental Impact Statement (EIS). Although the National Environmental Protection Act established the directive that EISs be written in plain language, understandable by the general public, previous studies revealed that this criteria had not been met. The goal of this effort was to study the impact of a variety of linguistic and non-linguistic elements on the comprehensibility/usability of an EIS. Principles from cohesion theory (an area of research describing effective design) were used to manipulate the design of select sections of two sample EISs. Each sample EIS was altered to manipulate the presence and/or absence of visual and linguistic cohesion; there were 8 versions of each of the two sections of the two sample EISs. Subjects were required to read select versions from each section of the two sample EISs and answer four short answer questions. The dependent variables were accuracy in answering the questions (a measure of coherence), and time to complete the task (a measure of usability). Statistical analyses provided no indication of significant differences between and among the

visual and linguistic cohesive elements. The underlying theory and experimental design may have been contributors to these results, but since this effort was constructed as a pilot study, there were many valuable observations made for future work in this area.

EFFECTS OF COHESION
ON
COHERENCE AND USABILITY
OF AN
ENVIRONMENTAL IMPACT STATEMENT

I. Introduction

The National Environmental Policy Act (NEPA) was signed into law on January 1, 1970. Its purpose was to address the need for a national environmental policy to guide the growing environmental consciousness and to help shape a national response. In essence, NEPA established the requirement that federal agencies must consider the environmental effects of, and any alternatives to, all proposals for major federal actions that significantly affect the quality of the environment.

Public participation is one of the fundamental elements of the NEPA statute. This information is contained, for the most part, within the Environmental Impact Statement (EIS). Specifically, NEPA Section 102(2)(C) requires that "copies of the EISshall be made available to the President, the Council on Environmental Quality and to the public as provided by the Freedom of Information Act" (Government Institutes, Inc., 1990:530). The Act also requires that federal agencies make information concerning restoring,

maintaining, and enhancing the quality of the environment available to individuals. Spensley writes that during the early years of NEPA, the threat of litigation over the EIS requirement caused federal agencies to overreact by including in their EIS's every environmental reference available (Spensley, 1993:321). This resulted in lengthy and unintelligible EIS's that, of course, were not read.

Weiss points out that this readability problem might have even more serious impacts:

Environmental engineers...are increasingly perceived as paid apologists for the people whose actions may foul the environment. Why? Because most Environmental Impact statements are so difficult and unpleasant to read that they make people suspicious. Even someone only moderately skeptical might suspect that readers are discouraged from reviewing the report too carefully. And, in a time when bright people worry that environmental laws can be manipulated and undermined by powerful interests, that inaccessible and unreadable EIS has come to be viewed as part of the problem instead of part of the solution (1989:236).

Weiss goes on to state that EISs may be seen by the public as a "deliberate effort to obscure the questions, to inhibit debate and intimidate all the opponents of a proposed project or action".

These public perceptions have not gone unnoticed by the Court system. Axline and Bonine investigated the legal implications of an unreadable EIS. They write that "Agency

misuse of the English language can result in violations of the agencies' obligations to inform the public. Agencies may even deliberately use language which is difficult to understand in order to discourage meaningful public review of their activities." The authors state that two courts have addressed this issue: each court concluded that the particular EIS in question was not sufficiently clear to satisfy NEPA requirements. In one decision, the court explained why EISs must be readable:

All features of an impact statement must be "written in language that is understandable to non-technical minds and yet contain enough scientific reasoning to alert specialists to particular problems within the field of their expertise." The reason for this standard is that impact statements must assist in rational, thoroughly informed decision making by officials higher up in the agency chain-of-command, including the Congress, the Executive, and the general public, some of whom may not possess the technical expertise of those who evaluate the impact and prepare environmental statements (Axline and Bonine, 1990:73).

The Council on Environmental Quality (CEQ), established as part of the NEPA, played a central role in the move to improve the public's perception of the EIS by strengthening the process. CEQ regulations emphasize the need to reduce excessive paperwork and focus on the essential information which is needed by decision-makers and the public. One of the CEQ's primary guidelines for an EIS is that

It shall provide full and fair discussion of significant environmental impacts and shall inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment (CEQ 1502.1).

The CEQ guidelines go on to state that this EIS must be "concise, clear, and to the point" and that "Environmental impact statements shall be written in plain language and may use appropriate graphics so that decisionmakers and the public can readily understand them. Agencies should employ writers of clear prose or editors to write, review, or edit statements..." (CEQ Part 1502.8).

However, the problem is not as simple as improving the ability of the writer, but extends to the entire plan preparation process. The writer has the difficult problem of presenting complex environmental information, consisting of technical and analytical data from chemistry, physics, medicine, microbiology, meteorology, and other disciplines as well. One can easily see that by the very nature of these assessments, the task of presenting an EIS in a clear, concise manner is difficult at best. How can one assume, first of all, that a writer will be adequately familiar with the technical issues at hand to be qualified to prepare such a document? From the EIS author's point of view, just summarizing the details of an environmental impact assessment means that they must collect, analyze, decipher,

and make judgments about data from a wide variety of sources and present them all in an unbiased manner. Now, they must convey this information, in "plain language" such that it is "concise, clear, and to the point" for what will undoubtedly be close scrutiny by the general public.

There is also the concurrent problem that environmental issues are gathering more and more attention. Past horrors and present dangers have made the public acutely aware of what might occur. Additionally, the public is conscious that they have a "right-to-know," and they want to be informed (hence the requirement to encourage public participation). They too, want to be given this information in terms they can readily interpret. When they are not, or when they are informed in terms that are unfamiliar, the Government will be held accountable.

In an attempt to address this public participation issue, the United States Air Force modified existing CEQ regulations to create Air Force Regulation 19-2 (Department of the Air Force, 1989). The intent of these guidelines was to give specific Air Force procedural requirements for the implementation of NEPA. However, these guidelines deal mainly with budgeting and chain-of-command issues and EIS authors are referred back to the CEQ regulations for preparation instructions: "This regulation gives specific procedural requirements for Air Force implementation of the

NEPA. In order to comply...the CEQ regulations and this regulation must be used together" (Department of the Air Force, 1989:1). In fact, the only guidance given for written communication is found in the CEQ regulation, listed as an attachment to AFR 19-2.

The bottom line seems to be that Government agencies dealing with touchy environmental issues have been mandated to "bring the public in" on these decisions; they have been told that the way to do this is by making EIS documents more readable. Perhaps the most important implication of this problem is that EISs which are unreadable are also unusable by the public, and usability is the key measure of the value of the document. To further complicate the problem, both of the regulations developed to encourage public "usability" contain ambitious statements attempting to dictate the production of a readily interpretable document; however, both are missing any guidance on *specifically* how this can be accomplished.

Research Objective.

The purpose of this research effort is to investigate the application of certain principles of effective communication to improve the comprehension, and ultimately the usability, of an EIS. Specifically, I plan to conduct an experimental study to evaluate the usability of two sample EISs. I will use principles derived from cohesion theory (an area of

research describing effective design) to manipulate the design of selected sections of each sample EIS. This research is considered a pilot study; much of the experimental design and methodology is being applied for the first time.

Overview of the Remaining Chapters.

Chapter II will provide a general overview of the format of a typical EIS. Chapter III contains both a review of research specifically investigating this problem, along with short discussions of the fundamental psycholinguistic concepts that form the baseline for this effort. Chapter IV discusses the methodology to investigate the EIS usability problem. Chapter V presents the results of the research, including a discussion of the results. Chapter VI contains conclusions, recommendations, and suggestions for future research.

II. Background

Function of an Environmental Impact Statement.

A full EIS is required if the lead agency decides that the proposed federal action could (not will) have a significant impact on the environment, or that the action may be viewed as controversial. It is this document that receives the highest degree of public scrutiny, and thus it is chosen as the object of this study.

The EIS is a document used by public officials to inform other state and federal agencies and the public of their proposed environmental actions. The EIS should describe the proposed action and its environmental impacts, alternative actions that could be taken and their impacts, and steps that could be taken to lessen these impacts. It is not viewed as a scientific document, but rather a legal document, prepared and issued by a government agency in its decision-making function

The EIS should identify the "agency's environmentally preferred alternative(s)" and the "agency's preferred alternative(s)". These two could be the same option. The first is the one that causes the least damage to the biological and physical environmental and best preserves, protects and enhances historical, cultural and natural resources. The "agency's preferred alternative" includes

other factors, such as monetary costs, land use plans, legal constraints, etc. The agency must explain its conclusion if the two are not the same.

The EIS is an official document issued by a government agency. It undergoes thorough internal reviews by scientific, administrative and legal experts to ensure that it reflects the agency's official position and is in compliance with all laws, regulations and environmental standards. If the proposal is environmentally unacceptable, an EIS must incorporate mitigative actions into the proposed action.

In general, the head of the federal agency issuing the EIS is responsible for the statement as a whole. Authors of specific sections of the EIS are responsible for their input; they are expected to be able to defend their analysis and conclusions in a court of law at a later date.

Environmental Impact Statement Format.

The Council on Environmental Quality has established guidelines for the format and contents of an EIS (1978).

The suggested format is as follows:

1. Cover sheet.
2. Summary. This section (less than 15 pages) should accurately and adequately summarize the entire EIS, stress conclusions, identify areas of concern raised by the public

and government officials, list unresolved issues, describe alternatives that were considered, and identify adverse environmental impacts that would not be avoided if the proposed action were allowed.

3. Table of contents.

4. Purpose and need. The need for the proposed action is discussed along with a brief history of the project being considered. Applicable laws, environmental and safety standards and policies that must be complied with are stated.

5. Alternatives including the proposed action. This is viewed as the most important section of the entire EIS. The environmental impacts of the proposed action and all reasonable alternatives (including the "no action" option) are presented in a comparative manner, defining the issues and providing a clear basis for choice among the options. Items that can be quantified (monetary costs and benefits, land areas committed, amount and value of resources used over the life of the action, health factors, radioactive and toxic releases, etc.) should be. Tables and graphs are typically used in this section to illustrate the similarities and differences between the options.

The alternatives section should evaluate all reasonable alternatives, and list the alternatives considered but eliminated from further analyses, with a brief discussion of

why. The "no action" alternative is analyzed in detail and forms the baseline against which the proposed and alternative actions are compared.

6. Affected environment. This section should contain a short, concise description of the areas to be affected by the proposed action and each alternative site before any action is taken. Items to be discussed include topography, solids, geology, groundwater, existing land and water use, water quality, climate, air quality, terrestrial and aquatic ecology, population and socioeconomic patterns on and close to the sites.

7. Environmental consequences. This section discusses the environmental and other impacts of the proposed action and alternatives. It should describe the environmental impact if the action is denied (the "no action" alternative). If construction of a facility is part of the proposed action, the EIS should address both the environmental impacts of construction and of plant operation after construction is completed.

8. List of preparers. Name, location, field of expertise, years of experience, and section(s) of the EIS prepared.

9. Appendix. Data and analyses relevant to the EIS and not readily available to the public may be included in the Appendix. Technical language may be used in this section.

In essence, the EIS is not meant to be a scientific report. It is a legal document whose primary function is its use by decisionmaking agencies in approving or not accepting the proposed action. The EIS is also used to inform the public and other government agencies of the environmental impacts of the proposed project. An EIS should be short and concise, analytical, conclusory, be written for a non-technical audience, discuss the pros and cons of the proposed action, and examine the impacts of all alternatives to the proposed action. The EIS should identify all adverse environmental impacts that cannot be avoided. The conclusions reached in the EIS should be clearly stated and supported by discussions and data in the text and by references to show that the agency has made the necessary analyses.

III. Literature Review

Overview.

There are several objectives to be set forth for this chapter. One objective is to justify the need for my research by discussing several past research efforts which have verified the problem of EIS readability. The second objective is to introduce the psycholinguistic concept of cohesion that will be investigated in this study. The third objective is to tie these concepts together, demonstrating the relationship between cohesion and comprehension (i.e. usability) issues in EISs.

EIS Readability/Usability Problems.

A series of research studies have looked at all aspects of the problem of EIS readability. Weiss looked at the composition of the EIS to evaluate overall credibility and clarity (1989:236). Gallagher and Jacobson examined typography, a graphical component of an EIS (Gallagher and Jacobson, 1993:99). The issue of "plain language" was addressed by Gallagher and Patrick-Riley (1989). All of these research studies established evidence and provided reasoning for the problems. These classes of problems are discussed below.

The clarity and credibility of many EISs are hindered by three types of errors (Weiss, 1989:236-240). First, there are strategic errors. Weiss defined these as "mistakes of

planning, failure to understand why the EIS is being written and for whom." Next there are structural errors: "mistakes of organization, failure to arrange the elements in the document in a way that makes them easy to follow". Finally, Weiss defined tactical errors as "mistakes of editing, failure to test and revise the texts for clarity and readability." Weiss concluded from his effort that each of these three errors could be solved. He suggested that improved leadership, employment of a professional editor and better document design might be the keys to EIS improvement.

CEQ regulations also call for EISs to have "appropriate graphics." Although there is no concrete definition in the regulations of what is meant by appropriate, one might assume that it means clear and informative. Typography is a component of graphics that looks at page layout factors; good typography can be related to an enhanced understanding of written ideas. Gallagher and Jacobson examined the typography of 150 EISs prepared by several agencies (1993:99-109). In this effort, the EISs were categorized according to several different typographical aspects (such as margins, type size, line length, justification). They found that the EISs ranged widely in typographic quality. The average EIS met fewer than 7 of ten "good" typographic criteria; in fact 12 percent were considered unreadable.

These results suggest that weak typography might seriously interfere with the public's ability to read an EIS.

The issue of "plain language" (as stated in CEQ 1978) has been addressed by Gallagher and Patrick-Riley (1989). They found the readability of a typical EIS document to be far above that of the general public. In fact, their study results indicated that "the plans are written for people with three to six years of college education" (1989:85). This is far above the tenth-grade level the researchers argued was the highest level at which plain language is supposed to be written (1989:86).

The EIS preparation process was examined by Elkin and Smith for proposals affecting Canadian National Parks (1988). Their intent was to produce criteria for reviewing screening reports (a particular form of an EIS used in Canada) and to provide recommendations to improve the quality of the reports. Their recommendations included the following guidance: 1) the reports should follow more closely the existing policies, 2) guidelines should be developed for the most commonly written reports, 3) technical information (like monitoring and surveillance data) should be presented in practical terms, and 4) emphasis should be placed on key information to eliminate unnecessary detail. This study is particularly relevant because it looked at solving the problem by improving the

process rather than temporarily masking the underlying issues by employing good editing skills.

From the results of these studies, it is apparent the problem has been adequately established. More research is needed to look at the extent of public comprehension and the role of other factors, like grammar and document organization on comprehension. Problems of this nature fall into the broad realm of usability research, an area of growing interest over the past several years. A summary of the relevant concepts of this area of research is presented below.

Document Design.

Schriver defines document design as "the theory and practice of creating comprehensible, usable, and persuasive texts" (1989:316). It is apparent from the increasing number of technical journals and textbooks devoted to this issue that document design has gained in popularity within the field of technical and scientific communication. Document design as a practice is not tied to a specific field, type of text, or particular audience. In fact Schriver also notes that "...while knowing about particular text genres, audiences, subject matters, and purposes can be helpful, such knowledge is often a limited and even inhibiting starting point" (1989:316).

Document design draws on research in many fields including cognitive and social psychology, human factors, psycholinguistics, sociology, typography and graphic design, and human and computer interaction. It concerns itself with "...how people produce and use text, particularly how they read, write, understand, and are motivated by text" (Schriver, 1989:316). Basically, document design deals with how a writer of anything can most effectively "get her point across" to the reader. At its best, good document design allows the reader to not only have a basic comprehension of the text, but also be able to make thoughtful decisions based on its clarity.

Using document design principles, I plan to conduct a research study to evaluate the "usability" of a typical EIS. Specifically, I will use principles derived from cohesion theory (an area of research employed by document designers) to manipulate selected sections of the EIS. However, before I can establish the connection between cohesion theory and text evaluation, and how they relate to EIS design, several related topics must be discussed in the following section.

Cohesion Theory.

First, let's consider the relationship between a "coherent" text and one that is "cohesive." Campbell argues "a *coherent*" discourse is one in which a recipient perceives

continuity as well as completeness, accuracy, and clarity... A cohesive discourse is one in which a producer has established continuity through the use of similar and proximate discourse elements" (1994, in press). The important things to note are that coherence is a perception of the recipient (i.e. the reader or listener) while cohesion describes the actual elements which the producer (i.e. writer) places in the discourse. For example, a 10-year-old might find an EIS unclear (hence incoherent) despite the fact that the EIS writer has placed certain cohesive elements in the document. Thus, the presence of elements in the document may or may not insure the desired perception of the reader.

The concept of continuity has been explored by Gestalt psychologists. They attempted to delineate the psychological principles which would explain why humans experience visual phenomena (like portions of text) as wholes. Gestalt psychologists believed that these principles were predictable; they developed a set of rules which describe these human perceptual characteristics. Based on these Gestalt principles, like proximity and similarity (see Wertheimer, 1938, for a detailed description of these principles), theories of discourse cohesion and coherence can be formulated and defended. These theories, based on Gestalt psychology, explain the source of many

difficulties reader encounter when interpreting texts and graphics, and they explain why well-designed pages and graphics are effective (Moore and Fitz, 1993:389). For example, Moore and Fitz illustrate the concept of closure in Figure 1 below.

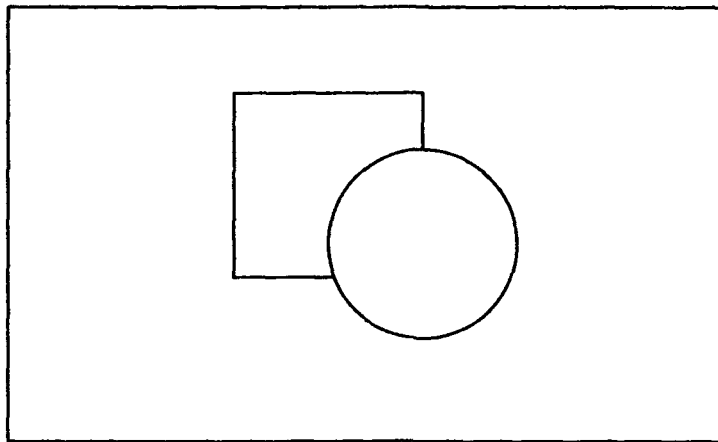


Figure 1. Example of the Gestalt Principle of Closure

In this example, the circle in the foreground prevents complete closure of the square; however the reader fills in the obstructed area and views this shape as a square. When designing a text, this concept of closure can be implemented when setting off graphics from written material. Drawing a box around a graphic area sets this area off from the text, thus stabilizing it and making it easier to distinguish.

As I stated above, continuity is established through the use of similar and proximate discourse elements. Discourse elements are any of the elements that may appear in written

texts. They are divided into two major categories: linguistic and non-linguistic. For example, some non-linguistic elements are visual (e.g. a photograph) or a typograph (e.g. boldface). Other linguistic elements are morpho-syntactic (e.g. verb tense) or semantic (e.g. synonyms). See Campbell, 1994 for a comprehensive listing.

I describe the categories of discourse elements for a reason. That is, most cohesion research has historically centered on linguistic devices (rather than non-linguistic). Campbell notes that little research has extended cohesion theory. Unfortunately, "A number of research studies which have applied Halliday and Hasan's theory of cohesion have provided conflicting or unclear results in terms of the relationship between semantic cohesive elements and coherence in a discourse" (Campbell, 1994). In response to this, Campbell established a research agenda to study the entire range of elements: semantic, other linguistic elements, and non-linguistic elements (1991;1994). This line of research attempts to answer the broad question: What role do cohesive discourse elements play in establishing coherence? In fact, Campbell has included several suggestions for future research that are particularly relevant to this research effort (1994). She has proposed that cohesion analysis may be more useful for predicting the usability of a document than coherence. She has suggested

that this hypothesis could be investigated by designing a study in which the research goal would be to determine the relative weight of syntactic versus visual similarity in predicting usability of a document.

Research Goal.

Thus, my goal was to study the impact of a variety of linguistic and non-linguistic cohesive elements on the comprehensibility/usability of an EIS. By doing this, two specific objectives were met. First, a comparison of a range of discourse elements was intended to test Campbell's hypothesis, that "cohesion produced through the use of visual similarity is more influential than that produced by syntactic similarity in determining usability" (1994). Second, if cohesion theory was able to answer these research questions, it would provide the tools for establishing guidelines to be used by producers of future Environmental Impact Statements.

IV. Methodology

Overview.

This chapter discusses the methodology employed to measure overall usability and coherence of an EIS. First, there is a description of the four discourse elements we tested, and illustrations of how they were presented in the EIS. This is followed by a section describing the methods used to measure subject performance. The final section of this chapter discusses the analysis measures we used to assess usability and coherence.

Discourse Elements.

Cohesiveness of four discourse elements was tested. The elements were: heading typography, whitespace, syntax, and tense. Heading typography and whitespace are considered visual elements while the remaining two are linguistic. The four discourse elements were changed in the following manner to reflect the presence (+ cohesion) or absence (- cohesion):

a) heading typography. Heading typography refers to the font, type size, etc., of headings in a document. Cohesive typography in the EISs was accomplished by presenting consistent section headings throughout the document. In other words, the same size and type of font was used, and underlining of headings was kept the same.

Lack of cohesive typography was demonstrated in the EISs by presenting similar sections using dissimilar headings (i.e. font size, type, boldface). See for example, Version B of the Delaware River Project EIS, found in Appendix A. This version demonstrates a lack of cohesive typography. Notice that headings of similar sections, such as: "Study Authority", "Planning Objectives", and "Problems, Needs and Public Concerns" are not presented in a consistent manner: boldface type is used in one case, italics are used in another. Version G (also in Appendix A) demonstrates the use of cohesive typography in that each section is presented using boldface type.

b) whitespace. Whitespace in a document is the use of indentation and spacing. Cohesive whitespace was presented in the EIS sections as consistent use of spacing and indentation of sections to indicate topic groupings. This use of cohesive whitespace is found in Version G of the Delaware River Project EIS Purpose and Need section (see Appendix A). For this version, subtopic section headings such as *Surface Water* and *Groundwater* are indented and spaced in the same manner. Dissimilar sections were presented without spacing to separate, along with variable indentation to present a lack of cohesive whitespace in the EIS versions (see example Version G, Appendix A).

c) syntax. + syntax (+ cohesion) is demonstrated through the use of repeated syntactic form. The following example, taken from a scientific journal and presented in Campbell's book (1994) illustrates this concept:

For five of the items, sentences exhibiting the greatest durational distinction between morphemic and non-morphemic/s/ *were chosen*. **For the remaining three items**, two sentences with distinction, and one with reverse distinction...*were selected* (emphasis added) (Walsh and Parker, 1983:204).

In this example, Campbell notes that both sentences have an initial prepositional phrase (highlighted in boldface) followed by a passive main clause (in italics).

An example of how + and - syntax was presented in this study is found in Appendix A, Version D of the Delaware River Project EIS Environmental Effects Section. Under the *Groundwater* subsection, the second, third, and fourth paragraphs begin as follows:

- 1) A study in which data were collected...
- 2) Data for the study were collected...
- 3) Data collected in the study...

Notice the use of repeated syntactic form. In Version D, the same three paragraphs begin:

- 1) The U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, collected data...

2) Data for the study were collected...

3) Study data indicate that ...

Notice that to demonstrate lack of cohesive syntax, repeated syntactic form was omitted in the text, eliminating the sense of continuity.

d) tense. In the EIS versions, cohesive tense was presented by consistent use of either past or present tense. Lack of cohesive tense (- continuity) was presented by mixing up the use of tense (the use of past with present). An example of this condition (- continuity) can be found in Appendix A, Version C, under the subsection entitled "*Main Channel Deepening-Delaware River, Philadelphia to the Sea (50 foot alternative)*". The third sentence reads as follows: Based on net benefits attributable to the three alternative depths, it *will be* concluded that.... Notice that this differs from Version G (cohesive tense), where the sentence read: Based on net benefits attributable to the three alternative depths, it *was* concluded that...

As mentioned above, Appendix A contains a complete set of the versions tested for the Delaware River EIS. Appendix B contains a subset of the Bergstrom AFB Closing versions; it was felt that the Delaware EIS versions were sufficient examples. The reader should refer to Appendix A for more detailed examples of how the cohesiveness of each type of discourse element was manipulated.

Description of Experiment.

Subjects. The experiment was conducted using employees of an Air Force organization. A total of 32 subjects were assigned at random to one of eight different subject groups. The subjects were not paid.

Materials. The effects of cohesiveness of four discourse elements (typography, white space, tense, and syntax) were evaluated by developing alternate versions of two actual EISs. We used two sections, (a) the Purpose and Needs and (b) Environmental Effects sections, from two separately prepared EISs: (a) a river channel dredging project along the Delaware River prepared by the Army Corps of Engineers (1990), and (b) the closure of Bergstrom Air Force Base prepared by the Department of the Air Force (1993). The objective of a Purpose and Needs section is to identify and describe the reason for the proposed action along with an overview of the project under consideration. This section also explains applicable environmental laws, standards, and policies that must be complied with. The Environmental Effects section discusses the impacts on the physical environment by the proposed action, results of any studies undertaken to assess the impacts, and any impacts if the action is not taken.

Each original EIS was altered to manipulate the presence and/or absence of visual and linguistic cohesion,

as described in the Discourse Element section (See Appendix A for a complete set of the Delaware River Project EIS versions). Each subject group received EISs with a different discourse element conditions. As Table 1 indicates, an incomplete square design was used to permit a two-way control in variation of the experimental units, i.e. column and row effects.

TABLE 1
ASSIGNMENT OF EIS VERSIONS TO SUBJECT GROUPS

SUBJECT GROUP	DELAWARE RIVER PROJECT		BERGSTROM AFB CLOSING	
	<u>Purpose & Needs Segment</u>	<u>Environmental Effects Segment</u>	<u>Purpose & Needs Segment</u>	<u>Environmental Effects Segment</u>
Group 1	Version A (-white space)	Version B (-typography)	Version C (-tense)	Version D (-syntax)
Group 2	Version B (-typography)	Version C (-tense)	Version D (-syntax)	Version E (-all visual)
Group 3	Version C (-tense)	Version D (-syntax)	Version E (-all visual)	Version F (- all linguistic)
Group 4	Version D (-syntax)	Version E (- all visual)	Version F (-all linguistic)	Version G (+all)
Group 5	Version E (-all visual)	Version F (-all linguistic)	Version G (+all)	Version H (-all)
Group 6	Version F (-all linguistic)	Version G (+all)	Version H (-all)	Version A (-white space)
Group 7	Version G (+all)	Version H (-all)	Version A (-white space)	Version B (-typography)
Group 8	Version H (-all)	Version A (-white space)	Version B (-typography)	Version C (-tense)

This design was utilized to control learning effects (the implications of this design are discussed in Chapter V).

Methods.

Procedure. For each session, subjects were asked to read two sections from two different EISs (as described above),

were given four short answer questions, covering the material contained in that version. The questions were designed to require subjects to formulate their answers from specific material within the four EIS sections. The specific questions pertaining to each version were adapted from a study performed by Elkin and Smith (1988:79). They developed a set of criteria for evaluating EIS screening reports based on the overall objective of improving the quality of these reports. For example, one criterion developed by Elkin and Smith was that an EIS should "look at alternative means for achieving project goals". From this criterion, we formulated the question "List the alternative projects which the U.S. Army Corps of Engineers has eliminated from further consideration". Another of their criteria, "Effective communication--is there a clear, concise statement of the purpose?" lead us to formulate the question "Why is the U.S. Corps of Engineers undertaking this navigation study of the Delaware River?". A complete listing of the Short Answer Questions for each of the four EIS sections is found in Appendix D.

Subjects were timed from the point at which they began reading to the point at which they had completed all four questions. Following this, each subject answered a series of multiple choice questions concerning their attitudes about the reading they just completed (this data will be

analyzed separately and therefore is not discussed in this thesis).

Subjects were allowed to ask questions about the experimental procedure, but not the specific content of the EIS versions. They were encouraged to write any comments as they were completing the multiple choice questions.

Analysis. The dependent variables in this experiment were accuracy in answering the short-answer questions about material contained in each version, and the time to complete the questions. Accuracy in answering questions was used as a measure of coherence while the time to complete the questions was used as a measure of usability.

In order to measure accuracy, experimenters and a subject matter expert determined the correct response to each short answer question. In addition, the relative difficulty of each question was used to develop a ranking. Each question was assigned a specific number of points based on the relative difficulty (1 point was assigned for the simplest question, 4 for the most difficult). There were no points assigned for partially correct or incomplete answers. The short answers of each subject were scored using this point system, and then tallied for each of the four EIS sections and for each of the eight subject group conditions.

V. Results and Discussion

Overview.

This objective of this chapter is to present and discuss the data collected and the analyses performed in this pilot study. First, background data about the subject population is presented (i.e. age range, sex, educational background). Second, data analyses are presented which considered usability issues. Finally, analyses performed to assess coherence are presented and discussed. The rationale for particular data analyses are included, along with an interpretation of each result. A more detailed discussion of the results, including conclusions can be found in Chapter VI.

Subject Demographics.

Thirty-two subjects were tested, 21 were male. Fourteen subjects were between the ages of 26-35, 11 were between 36-45, 4 were less than 25, the remainder (4) were 46-55. Twenty-one subjects had at least a bachelor's degree. Twenty-seven of the subjects were U.S. Air Force officers; the remainder were civilians employed by the Air Force Base.

Usability Analyses.

Appendix C presents the data set collected for the entire group of subjects. Included is the time data (in seconds) for each subject to complete each version of the two EIS sections for each of the two EISs (Delaware River and Bergstrom Air Force Base). Each subject received only four sections of the eight possible EIS versions (versions A-H).

In order to look for differences in subject performance for each EIS version, a one-way ANOVA was computed comparing time data for each EIS version. This data is presented in Table 2; the columns represent each EIS version, while the rows contain the time data (in seconds) for each instance that version was tested. The bottom row contains the mean times for each version. The ANOVA did not yield significant results ($p=.8025$). The ANOVA results were not surprising, probably due to the fact that an incomplete block experimental design was used--meaning that each subject was not tested across the full set of eight possible EIS versions.

TABLE 2
TIME DATA ARRANGED ACCORDING TO EACH EIS VERSION
(in seconds)

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
526	650	650	846	945	908	1080	1010
700	1065	1065	1242	1286	1395	755	569
726	735	735	1042	1105	1022	1429	863
707	955	955	919	1447	1077	1024	872
1607	812	654	852	1061	689	955	1607
757	853	1444	996	1347	914	1098	667
1199	706	627	701	677	1156	875	674
679	952	681	668	539	1456	719	1122
987	614	564	364	789	626	407	850
391	523	705	845	891	853	526	399
658	326	564	450	423	798	801	1163
684	311	397	438	696	360	651	911
549	701	794	554	414	363	503	591
745	410	570	720	908	575	685	454
536	441	399	532	426	420	1123	670
801	541	373	567	613	674	466	875
MEAN TIME FOR EACH VERSION							
770.6	753.4	698.6	733.5	847.9	830.4	818.6	738.1

results of this analysis is illustrated in Table 3. In other words, data from each subject tested on the same four EIS versions (e.g. versions ABCD, BCDE, CDEF, etc.) was averaged to get an overall time score. An ANOVA was then computed, using these mean time scores, looking for any differences as a result of the various testing sequences. The hypothesis was that even though individual differences between EIS version coherence time scores were impossible to identify because of the structure of the experimental

design, overall differences could be established for a combined data set. However, this ANOVA also did not yield any statistically significant results.

Based on the results of the initial ANOVA, the data set was dissected to look for the effects of age and education. In order to look for age effects, we categorized the time data for the three subjects from the youngest age range (25 years or less) as well as the that of the oldest subject age group (46-55 years). Unfortunately, subjects from these two age groups were not tested using similar EIS versions, making a statistically significant comparison impossible. When we attempted a comparison of education level, we found that the spread was not sufficient to warrant an analysis of any differences (over 70% of the subjects had at least a bachelor's degree plus some graduate school).

TABLE 3

TIME DATA ARRANGED ACCORDING TO VERSION SEQUENCE

EIS VERSION SEQUENCE (SUBJECT MEAN TIMES IN SECONDS)							
ABCD	BCDE	CDEF	DEFG	EFGH	FGHA	GHAB	HABC
614	575	663.5	759	658	815.5	941.25	1006.25
744.5	1095	881.75	989.75	777	995.75	560.5	616.5
624	575.25	569	991.25	811.5	814.25	742.25	496.75
559.5	634	749.75	552.75	962	897.5	697.5	482.25
MEAN TIME FOR EACH VERSION SEQUENCE							
635.5	719.8	716	823.2	802.1	880.8	735.4	650.4

The next ANOVA looked at any overall effects attributed to EIS version. In order to do this, data was reorganized

according to tested version sequence, and a mean time was computed giving one total time for each sequence. The results were not significant.

Another approach was then taken to assess the time data. The overall time data set was broken down according to each EIS and EIS section (Purpose and Need, Environmental Effects). This was done to eliminate any effects caused by the order in which various EIS sections were read and to simplify the data set. Table 4 contains the results of this analysis for the Delaware River Purpose and Need section. This separation of time data left four subject observations for each version. The data for Version H (the particular version with all four cohesive elements missing) was used as a control group, and comparisons with each of the remaining seven versions were made for this EIS section to look for an overall effect of cohesive elements. The comparison of version H with version E exhibited a statistically significant result ($p = .0425$). To remind the reader, version E was missing visual cohesion (whitespace and typography). None of the other ANOVAs yielded significant results.

TABLE 4
DELAWARE RIVER
PURPOSE AND NEED
TIME DATA ARRANGED ACCORDING TO VERSION
(in seconds)

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
526	868	650	846	945	908	1080	1010
700	1183	1065	1242	1286	1395	755	569
726	822	735	1042	1105	1022	1429	863
707	872	955	919	1447	1077	1024	872
MEAN TIME FOR EACH VERSION							
664.8	936.3	851.3	1012.3	1195.8	1100.5	1072	828.5

This procedure was repeated for the remaining three EIS sections. The results of this data analysis are summarized in Tables 5-7. Again, individual ANOVAs were accomplished for each version and version H. None of these results were statistically significant. Taking a closer look at the data presented in Tables 4-7, it is apparent that there are individual variations in the data; however, there are no distinct trends. A discussion of the data analysis problems is left to the end of this chapter.

TABLE 5

**DELAWARE RIVER
ENVIRONMENTAL EFFECTS
TIME DATA ARRANGED ACCORDING TO VERSION
(in seconds)**

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
1607	812	654	852	1061	689	955	1607
757	853	1444	996	1347	914	1098	667
1199	706	627	701	677	1156	875	674
679	952	681	668	539	1456	719	1122
MEAN TIME FOR EACH VERSION							
1060.5	830.8	851.5	804.3	906	1053.4	911.8	1017.5

TABLE 6

**BERGSTROM AFB CLOSING
PURPOSE AND NEED
TIME DATA ARRANGED ACCORDING TO VERSION
(in seconds)**

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
987	614	564	364	789	626	407	850
391	523	705	845	891	853	526	399
658	326	564	450	423	798	801	1163
684	311	397	438	696	360	651	911
MEAN TIME FOR EACH VERSION							
680	443.5	557.5	524.3	689.8	659.3	596.3	830.8

TABLE 7

**BERGSTROM AFB CLOSING
ENVIRONMENTAL EFFECTS
TIME DATA ARRANGED ACCORDING TO VERSION
(in seconds)**

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
549	701	794	554	414	363	503	591
745	410	570	720	908	575	685	454
536	441	399	532	426	420	1123	670
801	541	373	567	613	674	466	875
MEAN TIME FOR EACH VERSION							
657.8	523.3	534	593.3	590.3	508	694.3	647.5

Coherence Analyses.

As discussed in the Chapter IV, measures of coherence for this study were subject responses to a series of short answer questions presented at the beginning of each reading task. This data is summarized for each EIS version in Table 8 below. These numbers reflect point values based on rankings established by the experimenters for each set of questions for each version (see Chapter IV, Methodology). A score of 10 was the maximum number of points available, 0 was the minimum.

TABLE 8
SHORT ANSWER DATA FOR EACH SUBJECT
(a score of 10 is maximum)

SHORT ANSWER DATA ARRANGED ACCORDING TO VERSION							
Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
2	0	3	0	6	0	2	0
0	1	2	0	5	2	3	2
3	0	6	2	2	5	2	2
2	3	6	5	5	2	0	3
5	3	0	1	8	0	0	2
1	0	0	0	2	0	3	3
4	9	4	4	1	0	1	0
0	1	7	0	0	2	1	0
6	6	6	4	7	1	6	6
3	5	6	8	6	5	10	5
6	6	6	9	10	9	3	3
5	6	6	10	6	6	6	3
7	7	3	6	7	1	1	3
7	7	3	3	6	3	7	3
4	10	2	3	1	3	3	7
MEAN SCORE FOR EACH VERSION							
3.7	3.9	3.9	3.8	4.1	3.1	3.1	3.8

An ANOVA was computed to look for differences in short answer scores across all eight versions. The results were not statistically significant. Although the rationale for this result will be discussed in more detail at the end of this chapter, the initial experimental design is believed to be the largest contributor to these non-results.

Essentially, comparisons were tough to make, because, as with the time data, each subject was not tested across all eight versions.

In order to take a closer look at subject performance on each version, means were computed for the short answer point scores for versions A-H (the means appear at the bottom of Table 8. As the reader can see, the means do not differ significantly for any of the versions. This also explains the results of the ANOVA above; a data set this small would require a larger difference in the means to show statistically significant variances.

Finally, as was done for the usability assessment above, the original data set was decomposed to formulate smaller, more comparable data sets consisting of the results from each individual EIS and EIS section; these data sets are shown in Tables 9-12. ANOVAs were again computed across versions; none were significant. Again, as in the usability assessment, individual ANOVA statistics were computed for

each individual version and version H. None of these were significant.

TABLE 9

**DELAWARE RIVER
PURPOSE AND NEED
SHORT ANSWER DATA ARRANGED ACCORDING TO VERSION
(a score of 10 is maximum)**

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
2	0	3	0	6	0	2	0
0	1	2	0	5	2	3	2
3	0	6	2	2	5	2	2
2	3	6	5	5	2	0	3
MEAN SCORE FOR EACH VERSION							
1.8	1	4.3	1.8	4.5	2.3	1.8	1.8

TABLE 10

**DELAWARE RIVER PROJECT
ENVIRONMENTAL EFFECTS
SHORT ANSWER DATA ARRANGED ACCORDING TO VERSION
(a score of 10 is maximum)**

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
1	3	0	1	8	0	0	2
4	0	0	0	2	0	3	3
0	9	4	4	1	0	1	0
5	1	7	0	0	2	1	0
MEAN SCORE FOR EACH VERSION							
2.5	3.3	2.8	1.3	2.8	.5	1.3	1.3

TABLE 11

**BERGSTROM AFB CLOSING
PURPOSE AND NEED
SHORT ANSWER DATA ARRANGED ACCORDING TO VERSION
(a score of 10 is maximum)**

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
3	5	6	4	7	1	6	6
6	6	6	8	6	5	10	5
5	6	6	9	10	9	3	3
6	6	6	10	6	6	6	3
MEAN SCORE FOR EACH VERSION							
5	5.8	6	7.8	7.3	5.3	6.3	4.3

TABLE 12

**BERGSTROM AFB CLOSING
ENVIRONMENTAL EFFECTS
SHORT ANSWER DATA ARRANGED ACCORDING TO VERSION
(a score of 10 is maximum)**

Version A	Version B	Version C	Version D	Version E	Version F	Version G	Version H
7	3	3	6	7	1	1	3
4	10	2	6	3	7	3	10
10	3	3	3	1	3	3	7
7	7	3	3	3	7	7	5
MEAN SCORE FOR EACH VERSION							
7	5.8	2.8	4.5	3.5	4.5	3.5	6.3

VI. Conclusions and Recommendations

The underlying theory and experimental design made this research very difficult to conceive and to plan. Because of these factors, this effort was constructed as a pilot study, to test out hypotheses while making observations for future experimental work. It is the objective of this final chapter to draw some final conclusions from the results and to make suggestions for further study in this area.

The effects of consistent typography, etc. (what we call "cohesion") have been well documented in other research. For instance, past work has focused on typography and the link to comprehension. Research by Diehl and Mikulecky supported the theory that weak typography discouraged readers: When given text with poor use of typography and whitespace, some subjects became fatigued, leading to low reading comprehension; others did not read the text at all (1981). Further research in the broad area of typography found that good typography (like use of boldface type) aided in retrieval and learning (Hershberger and Terry, 1965: 55-60; Foster and Coles, 1977: 353-365). In another study, Rubens and Rubens presented subjects with different manuals, each containing a different graphic format (i.e. typography and whitespace), but the same content (1988: 213-233). They found that format did have an influence on performance; there were significant differences in the time it took

subjects to answer questions concerning the material. Thus, comprehension was affected by these factors.

On the other hand, Gestalt theory has been employed to explain the effectiveness of document design and graphics (Moore and Fitz, 1993; Bernhardt, 1986: 66-77). Moore and Fitz discussed in their article, the principles of figure-ground segregation, symmetry, closure, proximity, good continuation, and similarity to provide a basis for improving textual design. Bernhardt discussed similar applications of these Gestalt principles to text, stating that "By studying and writing texts which display their structures through white space, graphic patterning, enumerative sequences...writers can gain a heightened sense of orderly progression." In other words, research supports the application of theories similar to those which formed the foundation for this study.

Therefore, we must consider why similar results were not obtained in this study. A number of factors may have been contributors.

First, when this study was originally envisioned, the implications of our experimental design were overlooked. The original intent was to control for learning effects and to limit the amount of required subject participation time. However, the impact of formulating an incomplete subject data set were not apparent. It appears, however, that this

oversight may have confounded our results by not giving us a complete data set to analyze. As we have noted previously, each subject only received 4 of the 8 possible Versions. In order to properly analyze data sets, the data must be collected in a specific balanced manner, which varies according to the number of treatments. In the case of this study, the data was not collected in the balanced manner that would lend itself to an appropriate application of statistics, like ANOVA. Proper handling of this design, called a randomized incomplete block, is discussed in Bradley (1954).

Second, we also found that the factors considered in the data analysis were extraordinarily complicated. This was not apparent to us from the onset of this study. In order to achieve external validity, we were looking at two EISs, two sections of each EIS, eight separate versions, and various sequences of presentation. This degree of complexity served to make a straightforward data analysis difficult. Perhaps one EIS section would have been sufficient for data collection, provided the number of subjects was large enough, and each subject received all 8 versions of the EIS.

Third, other difficulties may have been encountered because of the procedure used to collect the data. After observing each experimental session, we found that most

subjects read through each version completely before attempting to answer the questions. Because most subjects did not employ the strategy of answering the questions as soon as they were able, effects of the cohesiveness of each discourse element may have been lessened or eliminated. A time limit might have overcome this limitation. That is, we suggest that the subjects be coerced into searching the document quickly, with the specific objective of efficiently answering each question. This may have been a better measure of the actual usability of the document.

Fourth, although the statistical analyses did not allow us to make a concrete recommendation on how to improve the quality of an EIS, we have certainly established the problem. These EISs are impossible to read, and worse, impossible to comprehend. Evidence of this is found in the number of 0 comprehension scores (a total of 21). Much work has gone into proving that EISs are indeed this poor, and this pilot study started down the right road to determine why. This study took an innovative approach to determine why; it seems that there is ample justification to continue to apply variations of these theories.

Appendix A: Delaware River Project Test Versions

GENERAL INFORMATION

Appendix A contains a complete set of test versions for each section: Purpose and Need and Environmental Effects. Each version is presented in the same format given to the subjects, except Version letters have been added at the beginning of each to allow the reader to identify the text. The eight Purpose and Need versions are presented first, followed by the Environmental Effects versions.

VERSION A PURPOSE AND NEED

Study Authority

The Delaware River Comprehensive Navigation Study was authorized by a resolution adopted by the United States House of Representative, Committee on public Works, dated December 2, 1970. The study also responds to two resolutions adopted by the United States Senate, Committee on Public Works, dated March 1, 1954 and September 20, 1974. These resolutions are contained in the Introduction section of the main report.

Planning Objectives

The purpose of this planning study is to evaluate the need for a and alternative methods of improving the navigation channel to accommodate commercial vessels transiting the Delaware River between Philadelphia, Pennsylvania and the mouth of the Delaware Bay (Figure 1), as well as its tributary projects that support commercial navigation. The need is based on current shipping problems resulting from delays in intermodal transfers, insufficient channel dimensions and other physical aspects affecting waterborne commerce.

Problems, Needs and Public Concerns

The major problem associated with the existing Delaware River, Philadelphia to the Sea, Federal navigation project (Figures 2 and 3) is an insufficient channel depth to accommodate bulk commodity vessels at design drafts. The commodities, which include crude oil, coal and iron ore, are currently shipped in partially loaded vessels due to draft restrictions.

Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude and refined oil products are the highest volume commodity in United States freight trade and account for the overwhelming majority of tonnage moved in the Delaware River. The refineries located along the Delaware River account for a significant portion of the refinery capacity of the United States and provide petroleum products throughout the mid-Atlantic states. A large amount of the crude oil that comes to the Delaware River facilities is lightered. Lightering is the transfer of cargo from a large, deep-draft vessel to a smaller vessel or barge to maximize the cargo tonnage carried over a long voyage. Vessels that require a depth greater than 40 feet must transfer a portion of their cargo in Delaware Bay before they can travel upriver. In addition, many of the coal vessels and iron ore vessels are also partially loaded. Provision of a deeper channel would reduce or eliminate inefficient non-structural practices such as lightering and light loading, now employed for restricted vessels. In addition, several users are likely to utilize larger vessels if a deeper channel is provided.

A critical element in the development of any navigation study is the disposal of dredged material. Approximately 5.4 million cubic yards of material for the existing 40' deep channel project are annually dredged from the Delaware River between Philadelphia and the sea. Acquisition of disposal areas for the existing channel is now solely a Federal responsibility. There are seven active upland disposal areas for the Philadelphia to the sea project. Additional dredged material disposal sites are needed to adequately handle dredged material from the existing Federal project past the year 2020. New disposal areas are also required for new construction and maintenance of a deeper channel. A secondary goal of this study is to upgrade present disposal areas and locate additional sites with sufficient capacity to handle deepening and maintenance dredging operations over the projects' full 50 year project life (2005 - 2055).

Public concerns with regard to the Delaware River and bay include protection of natural resources, specifically wetlands, fisheries and wildlife; air and water quality control; protection of municipal water supplies from salinity and chemical contamination; protection of cultural resources; and enhancement of economic conditions within the Delaware Valley. A current concern with regard to water quality is

prevention of oil spills in the river. A rash of major spills in 1989, including one in the Delaware River, has focused National attention on the safety of oil tankers and the potential for environmental damage.

ALTERNATIVES

Plans Eliminated from Future Study

The Delaware River Comprehensive Navigation Study addresses navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures include channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that are eliminated from further study.

Main Channel Deepening - Delaware River, Philadelphia to the Sea (50 foot alternative). Initial considerations of deepening the existing Delaware River navigation channel from Philadelphia to the sea included alternative depths of 42, 45 and 50 feet below mean low water (mlw). Analyses included calculations of initial dredging quantities, rock excavation, utility relocations, dredged material disposal and increased annual maintenance. Based on net benefits attributable to the three alternative depths, it was concluded that a 50-foot mlw project would not be economically feasible under the conditions occurring at that time. As such, that alternative was eliminated from further study. Additional study of deepening up to 45 feet mlw was found warranted in order to determine an optimum channel depth.

Main Channel Deepening - Delaware River, Philadelphia to Trenton. Initial considerations of deepening the existing Delaware River navigation channel included the option of deepening only from Philadelphia to Trenton (Figure 1). Alternative depths included 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river identified the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that would benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, additional study of deepening from Philadelphia to Trenton were not warranted.

Channel Realignment at the Benjamin Franklin Bridge

Initial considerations included the possibility of realigning the existing Delaware River navigation channel at the Benjamin Franklin Bridge. The channel now passes underneath the bridge close to the west abutment (Figure 2). This alignment provides a minimum vertical clearance of 129 feet mean high water (mhw), which is the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge would provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determined that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, because this realignment improvement would serve a single user firm or individual, with no additional user identified for the future, additional study of this alternative was not warranted.

Channel Realignment at Marcus Hook, Pennsylvania

Initial considerations included the possibility of realigning the existing Delaware River navigation channel through the Marcus Hook, Chester and Eddystone ranges (Figure 2). The existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side would avoid extensive rock removal, but would require significant dredging of sediment due to the shallow nature of this section of the river. Formulation of these alternatives was conducted on a least cost basis since benefits would remain constant regardless of alignment. The formulation demonstrated that channel deepening along the existing alignment at Marcus Hook was more cost-effective than realigning the channel to avoid rock excavation. Thus, additional study of this realignment was not warranted.

Anchorage Modification - Delaware River, Philadelphia to the Sea. Initial considerations included the possibility of modifying anchorages between Philadelphia and the Sea. A series of six Federally authorized anchorages and 13 naturally deep, U.S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and the Delaware Bay. Included are general and

special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages are generally used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space for favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, is most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U.S. Coast Guard records indicated that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concluded that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage should be modified to provide a compatible depth. Modifications to the Mantua Creek and an additional portion of the Marcus Hook Anchorage would be needed to continue safe vessel docking practices. Thus, additional study of anchorage modifications was warranted.

No Action. Initial considerations also included the possibility of no action or modifications of the Delaware River navigation channel. The no action plan would entail continued maintenance of the currently authorized Delaware River, Philadelphia to the sea, Federal navigation channel (Figures 2 and 3). This project, last modified in 1958, provides a 40 foot deep mlw channel from Allegheny Avenue in Philadelphia, Pennsylvania to deep water in Delaware Bay. Channel widths vary within the river. Through Philadelphia Harbor, an asymmetric channel is 40 feet deep and between 400 and 500 feet wide on the west side of the river, and 37 feet deep and between 500 and 600 feet wide on the east side of the river. From Philadelphia Harbor to Bombay Hook in Delaware Bay, the channel is 800 feet wide. The channel increases to 1,000 feet wide in Delaware Bay. There are 19 designated anchorages of which 13 occur in naturally deep water. The project requires average annual maintenance dredging of 5,400,000 cubic yards of material. Dredged material is placed in seven Federally operated, upland dredged material disposal areas located along the New Jersey side of the river, and an open water site located in Delaware Bay.

While separate inbound and outbound lanes are provided with the existing channel, vessels generally navigate the center of the channel, except when in a passing situation. Vessels with drafts up to 37 feet can navigate the channel without consideration of tidal stage. Vessels with drafts between 37 and 40 feet navigate the channel by using the tides. Inbound vessels generally leave the pilot transfer area at the mouth of Delaware Bay 2.5 hours before high tide, and travel upriver at speeds between eight and 13 knots. This provides sufficient time for vessels to pass the rock ledge at Marcus Hook with the water level at least three feet above local mean low water. This allows a minimum of three feet underkeep clearance and provides enough time to dock before the current changes after high tide. Overall trip time for inbound vessels is 7.5 hours. Loaded outbound vessels leave Philadelphia two hours before high tide to clear Marcus Hook with maximum clearance. By the time low tide occurs, the ship has traveled to naturally deep water in the upper bay. Ships then wait for a rising tide to finish the trip, taking a total of 10.5 hours. Vessel speeds are adjusted to limit squat to about two feet on inbound trips and one foot on outbound trips.

Without implementation of the proposed improvements to the Delaware River Philadelphia to the sea navigation channel, the maximum draft of vessels, transiting the river would be limited to the draft now accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of tankers and dry bulk carriers are currently forced to employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic viability of the operators. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterbound commerce with other East Coast ports. Thus, the possibility of no action was not warranted.

VERSION B

PURPOSE AND NEED

Study Authority

The Delaware River Comprehensive Navigation Study was authorized by a resolution adopted by the United States House of Representative, Committee on public Works, dated December 2, 1970. The study also responds to two resolutions adopted by the United States Senate, Committee on Public Works, dated March 1, 1954 and September 20, 1974. These resolutions are contained in the Introduction section of the main report.

Planning Objectives

The purpose of this planning study is to evaluate the need for a and alternative methods of improving the navigation channel to accommodate commercial vessels transiting the Delaware River between Philadelphia, Pennsylvania and the mouth of the Delaware Bay (Figure 1), as well as its tributary projects that support commercial navigation. The need is based on current shipping problems resulting from delays in intermodal transfers, insufficient channel dimensions and other physical aspects affecting waterborne commerce.

Problems, Needs and Public Concerns

The major problem associated with the existing Delaware River, Philadelphia to the Sea, Federal navigation project (Figures 2 and 3) is an insufficient channel depth to accommodate bulk commodity vessels at design drafts. The commodities, which include crude oil, coal and iron ore, are currently shipped in partially loaded vessels due to draft restrictions.

Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude and refined oil products are the highest volume commodity in United States freight trade and account for the overwhelming majority of tonnage moved in the Delaware River. The refineries located along the Delaware River account for a significant portion of the refinery capacity of the United States and provide petroleum products throughout the mid-Atlantic states. A large amount of the crude oil that comes to the Delaware River facilities is lightered. Lightering is the transfer of cargo from a large, deep-draft vessel to a smaller vessel or barge to maximize the cargo tonnage carried over a long voyage. Vessels that require a depth greater than 40 feet must transfer a portion of their cargo in Delaware Bay before they can travel upriver. In addition, many of the coal vessels and iron ore vessels are also partially loaded. Provision of a deeper channel would reduce or eliminate inefficient non-structural practices such as lightering and light loading, now employed for restricted vessels. In addition, several users are likely to utilize larger vessels if a deeper channel is provided.

A critical element in the development of any navigation study is the disposal of dredged material. Approximately 5.4 million cubic yards of material for the existing 40' deep channel project are annually dredged from the Delaware River between Philadelphia and the sea. Acquisition of disposal areas for the existing channel is now solely a Federal responsibility. There are seven active upland disposal areas for the Philadelphia to the sea project. Additional dredged material disposal sites are needed to adequately handle dredged material from the existing Federal project past the year 2020. New disposal areas are also required for new construction and maintenance of a deeper channel. A secondary goal of this study is to upgrade present disposal areas and locate additional sites with sufficient capacity to handle deepening and maintenance dredging operations over the projects' full 50 year project life (2005 - 2055).

Public concerns with regard to the Delaware River and bay include protection of natural resources, specifically wetlands, fisheries and wildlife; air and water quality control; protection of municipal water

supplies from salinity and chemical contamination; protection of cultural resources; and enhancement of economic conditions within the Delaware Valley. A current concern with regard to water quality is prevention of oil spills in the river. A rash of major spills in 1989, including one in the Delaware River, has focused National attention on the safety of oil tankers and the potential for environmental damage.

ALTERNATIVES

Plans Eliminated from Future Study

The Delaware River Comprehensive Navigation Study addresses navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures include channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that are eliminated from further study.

Main Channel Deepening - Delaware River, Philadelphia to the Sea (50 foot alternative). Initial considerations of deepening the existing Delaware River navigation channel from Philadelphia to the sea included alternative depths of 42, 45 and 50 feet below mean low water (mlw). Analyses included calculations of initial dredging quantities, rock excavation, utility relocations, dredged material disposal and increased annual maintenance. Based on net benefits attributable to the three alternative depths, it was concluded that a 50-foot mlw project would not be economically feasible under the conditions occurring at that time. As such, that alternative was eliminated from further study. Additional study of deepening up to 45 feet mlw was warranted in order to determine an optimum channel depth.

Main Channel Deepening - Delaware River, Philadelphia to Trenton. Initial considerations of deepening the existing Delaware River navigation channel included the option of deepening only from Philadelphia to Trenton (Figure 1). Alternative depths included 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river identified the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that would benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, additional study of deepening from Philadelphia to Trenton were not warranted.

Channel Realignment at the Benjamin Franklin Bridge. Initial considerations included the possibility of realigning the existing Delaware River navigation at the Benjamin Franklin Bridge. The channel now passes underneath the bridge close to the west abutment (Figure 2). This alignment provides a minimum vertical clearance of 129 feet mean high water (nhw), which is the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge would provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determined that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, because this realignment improvement would serve a single user firm or individual, with no additional user identified for the future, additional study of this alternative was not warranted.

Channel Realignment at Marcus Hook, Pennsylvania. Initial considerations included the possibility of realigning the existing Delaware River navigation channel between Philadelphia and the sea through the Marcus Hook, Chester and Eddystone ranges (Figure 2). The existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side would avoid extensive rock removal, but would require significant dredging of sediment due to the shallow nature of this section of the river. Formulation of these alternatives was conducted on a least cost basis since benefits would

remain constant regardless of alignment. The formulation demonstrated that channel deepening along the existing alignment at Marcus Hook was more cost-effective than realigning the channel to avoid rock excavation. Thus, additional study of this realignment was not warranted.

Anchorage Modification - Delaware River, Philadelphia to the Sea. Initial considerations included the possibility of modifying anchorages between Philadelphia and the Sea. A series of six Federally authorized anchorages and 13 naturally deep, U.S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and the Delaware Bay. Included are general and special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages are generally used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space for favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, is most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U.S. Coast Guard records indicated that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concluded that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage should be modified to provide a compatible depth. Modifications to the Mantua Creek and an additional portion of the Marcus Hook Anchorage would be needed to continue safe vessel docking practices. Thus, additional study of anchorage modifications was warranted.

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accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of tankers and dry bulk carriers are currently forced to employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic viability of the operators. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterbound commerce with other East Coast ports. Thus, the possibility of no action was not warranted.

VERSION C

PURPOSE AND NEED

Study Authority

The Delaware River Comprehensive Navigation Study was authorized by a resolution adopted by the United States House of Representative, Committee on public Works, dated December 2, 1970. The study also responds to two resolutions adopted by the United States Senate, Committee on Public Works, dated March 1, 1954 and September 20, 1974. These resolutions are contained in the Introduction section of the main report.

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The purpose of this planning study is to evaluate the need for a and alternative methods of improving the navigation channel to accommodate commercial vessels transiting the Delaware River between Philadelphia, Pennsylvania and the mouth of the Delaware Bay (Figure 1), as well as its tributary projects that support commercial navigation. The need is based on current shipping problems resulting from delays in intermodal transfers, insufficient channel dimensions and other physical aspects affecting waterborne commerce.

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Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude and refined oil products are the highest volume commodity in United States freight trade and account for the overwhelming majority of tonnage moved in the Delaware River. The refineries located along the Delaware River account for a significant portion of the refinery capacity of the United States and provide petroleum products throughout the mid-Atlantic states. A large amount of the crude oil that comes to the Delaware River facilities is lightered. Lightering is the transfer of cargo from a large, deep-draft vessel to a smaller vessel or barge to maximize the cargo tonnage carried over a long voyage. Vessels that require a depth greater than 40 feet must transfer a portion of their cargo in Delaware Bay before they can travel upriver. In addition, many of the coal vessels and iron ore vessels are also partially loaded. Provision of a deeper channel would reduce or eliminate inefficient non-structural practices such as lightering and light loading, now employed for restricted vessels. In addition, several users are likely to utilize larger vessels if a deeper channel is provided.

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Public concerns with regard to the Delaware River and bay include protection of natural resources, specifically wetlands, fisheries and wildlife; air and water quality control; protection of municipal water supplies from salinity and chemical contamination; protection of cultural resources; and enhancement of

economic conditions within the Delaware Valley. A current concern with regard to water quality is prevention of oil spills in the river. A rash of major spills in 1989, including one in the Delaware River, has focused National attention on the safety of oil tankers and the potential for environmental damage.

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Main Channel Deepening - Delaware River, Philadelphia to Trenton. Initial considerations of deepening the existing Delaware River navigation channel included the option of deepening only from Philadelphia to Trenton (Figure 1). Alternative depths include 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river will identify the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that will benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, additional study of deepening from Philadelphia to Trenton is not warranted.

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VERSION D

PURPOSE AND NEED

Study Authority

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ALTERNATIVES

Plans Eliminated from Future Study

The Delaware River Comprehensive Navigation Study addresses navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures include channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that are eliminated from further study.

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Main Channel Deepening - Delaware River, Philadelphia to Trenton. A study was conducted to determine the feasibility of deepening the existing Delaware River navigation channel from Philadelphia to Trenton (Figure 1). Alternative depths included 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river identified the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that would benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, no further studies were conducted to consider potential modifications of the Delaware River, Philadelphia to Trenton project.

Channel Realignment at the Benjamin Franklin Bridge. The existing Delaware River navigation channel passes underneath the Benjamin Franklin Bridge close to the west abutment (Figure 2). This alignment provides a minimum vertical clearance of 129 feet mean high water (nhw), which is the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge would provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determined that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, Federal participation is not warranted when the improvement would serve a single user firm or individual, with no additional user identified for the future. Therefore, studies of this alternative were terminated.

Channel Realignment at Marcus Hook, Pennsylvania. Study of the potential deepening of the Delaware River navigation channel between Philadelphia and the Sea included consideration of realigning the channel through the Marcus Hook, Chester and Eddystone ranges (Figure 2). The existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side would avoid extensive rock removal, but would require significant dredging of sediment due to the shallow nature of this section of the river. Formulation of these alternatives was conducted on a least cost basis since benefits would remain constant regardless of alignment. The formulation demonstrated that channel

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Anchorage Modification - Delaware River, Philadelphia to the Sea. A series of six Federally authorized anchorages and 13 naturally deep, U.S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and the Delaware Bay. Included are general and special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages are generally used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space for favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, is most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U.S. Coast Guard records indicated that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concluded that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage should be modified to provide a compatible depth. Modifications to the Mantua Creek and an additional portion of the Marcus Hook Anchorage would be needed to continue safe vessel docking practices.

No Action. The no action plan would entail continued maintenance of the currently authorized Delaware River, Philadelphia to the sea, Federal navigation channel (Figures 2 and 3). This project, last modified in 1958, provides a 40 foot deep mhw channel from Allegheny Avenue in Philadelphia, Pennsylvania to deep water in Delaware Bay. Channel widths vary within the river. Through Philadelphia Harbor, an asymmetric channel is 40 feet deep and between 400 and 500 feet wide on the west side of the river, and 37 feet deep and between 500 and 600 feet wide on the east side of the river. From Philadelphia Harbor to Bombay Hook in Delaware Bay, the channel is 800 feet wide. The channel increases to 1,000 feet wide in Delaware Bay. There are 19 designated anchorages of which 13 occur in naturally deep water. The project requires average annual maintenance dredging of 5,400,000 cubic yards of material. Dredged material is placed in seven Federally operated, upland dredged material disposal areas located along the New Jersey side of the river, and an open water site located in Delaware Bay.

While separate inbound and outbound lanes are provided with the existing channel, vessels generally navigate the center of the channel, except when in a passing situation. Vessels with drafts up to 37 feet can navigate the channel without consideration of tidal stage. Vessels with drafts between 37 and 40 feet navigate the channel by using the tides. Inbound vessels generally leave the pilot transfer area at the mouth of Delaware Bay 2.5 hours before high tide, and travel upriver at speeds between eight and 13 knots. This provides sufficient time for vessels to pass the rock ledge at Marcus Hook with the water level at least three feet above local mean low water. This allows a minimum of three feet underkeep clearance and provides enough time to dock before the current changes after high tide. Overall trip time for inbound vessels is 7.5 hours. Loaded outbound vessels leave Philadelphia two hours before high tide to clear Marcus Hook with maximum clearance. By the time low tide occurs, the ship has traveled to naturally deep water in the upper bay. Ships then wait for a rising tide to finish the trip, taking a total of 10.5 hours. Vessel speeds are adjusted to limit squat to about two feet on inbound trips and one foot on outbound trips.

Without implementation of the proposed improvements to the Delaware River Philadelphia to the sea navigation channel, the maximum draft of vessels, transiting the river would be limited to the draft now accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of tankers and dry bulk carriers are currently forced to employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic

viability of the operators. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterbound commerce with other East Coast ports.

VERSION E

PURPOSE AND NEED

Study Authority

The Delaware River Comprehensive Navigation Study was authorized by a resolution adopted by the United States House of Representative, Committee on public Works, dated December 2, 1970. The study also responds to two resolutions adopted by the United States Senate, Committee on Public Works, dated March 1, 1954 and September 20, 1974. These resolutions are contained in the Introduction section of the main report.

Planning Objectives

The purpose of this planning study is to evaluate the need for a and alternative methods of improving the navigation channel to accommodate commercial vessels transiting the Delaware River between Philadelphia, Pennsylvania and the mouth of the Delaware Bay (Figure 1), as well as its tributary projects that support commercial navigation. The need is based on current shipping problems resulting from delays in intermodal transfers, insufficient channel dimensions and other physical aspects affecting waterborne commerce.

Problems, Needs and Public Concerns

The major problem associated with the existing Delaware River, Philadelphia to the Sea, Federal navigation project (Figures 2 and 3) is an insufficient channel depth to accommodate bulk commodity vessels at design drafts. The commodities, which include crude oil, coal and iron ore, are currently shipped in partially loaded vessels due to draft restrictions.

Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude and refined oil products are the highest volume commodity in United States freight trade and account for the overwhelming majority of tonnage moved in the Delaware River. The refineries located along the Delaware River account for a significant portion of the refinery capacity of the United States and provide petroleum products throughout the mid-Atlantic states. A large amount of the crude oil that comes to the Delaware River facilities is lightered. Lightering is the transfer of cargo from a large, deep-draft vessel to a smaller vessel or barge to maximize the cargo tonnage carried over a long voyage. Vessels that require a depth greater than 40 feet must transfer a portion of their cargo in Delaware Bay before they can travel upriver. In addition, many of the coal vessels and iron ore vessels are also partially loaded. Provision of a deeper channel would reduce or eliminate inefficient non-structural practices such as lightering and light loading, now employed for restricted vessels. In addition, several users are likely to utilize larger vessels if a deeper channel is provided.

A critical element in the development of any navigation study is the disposal of dredged material. Approximately 5.4 million cubic yards of material for the existing 40' deep channel project are annually dredged from the Delaware River between Philadelphia and the sea. Acquisition of disposal areas for the existing channel is now solely a Federal responsibility. There are seven active upland disposal areas for the Philadelphia to the sea project. Additional dredged material disposal sites are needed to adequately handle dredged material from the existing Federal project past the year 2020. New disposal areas are also required for new construction and maintenance of a deeper channel. A secondary goal of this study is to upgrade present disposal areas and locate additional sites with sufficient capacity to handle deepening and maintenance dredging operations over the projects' full 50 year project life (2005 - 2055).

Public concerns with regard to the Delaware River and bay include protection of natural resources, specifically wetlands, fisheries and wildlife; air and water quality control; protection of municipal water supplies from salinity and chemical contamination; protection of cultural resources; and enhancement of economic conditions within the Delaware Valley. A current concern with regard to water quality is prevention of oil spills in the river. A rash of major spills in 1989, including one in the Delaware River, has focused National attention on the safety of oil tankers and the potential for environmental damage.

ALTERNATIVES

Plans Eliminated from Future Study

The Delaware River Comprehensive Navigation Study addresses navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures include channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that are eliminated from further study.

Main Channel Deepening - Delaware River, Philadelphia to the Sea (50 foot alternative). Initial considerations of deepening the existing Delaware River navigation channel from Philadelphia to the sea included alternative depths of 42, 45 and 50 feet below mean low water (mlw). Analyses included calculations of initial dredging quantities, rock excavation, utility relocations, dredged material disposal and increased annual maintenance. Based on net benefits attributable to the three alternative depths, it was concluded that a 50-foot mlw project would not be economically feasible under the conditions occurring at that time. As such, that alternative was eliminated from further study. Additional study of deepening up to 45 feet mlw was warranted in order to determine an optimum channel depth.

Main Channel Deepening - Delaware River, Philadelphia to Trenton. Initial considerations of deepening the Delaware River navigation channel included deepening only from Philadelphia to Trenton (Figure 1). Alternative depths included 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river identified the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that would benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, additional study of deepening from Philadelphia to Trenton was not warranted.

Channel Realignment at the Benjamin Franklin Bridge.

Initial considerations included the possibility of realigning the existing Delaware River navigation channel at the Benjamin Franklin Bridge. The channel now passes underneath the bridge close to the west abutment (Figure 2). This alignment provides a minimum vertical clearance of 129 feet mean high water (nhw), which is the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge would provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determined that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, because this realignment improvement would serve a single user firm or individual, with no additional user identified for the future, additional study of this alternative was not warranted.

Channel Realignment at Marcus Hook, Pennsylvania.

Initial considerations included the possibility of realigning the existing Delaware River navigation channel through the Marcus Hook, Chester and Eddystone ranges (Figure 2). The existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side would avoid extensive rock removal, but would require significant dredging of sediment due to the shallow nature of this section of the river. Formulation of these alternatives was conducted on a least cost basis since benefits would remain constant regardless of alignment. The formulation demonstrated that channel deepening along the existing alignment at Marcus Hook was more cost-effective than realigning the channel to avoid rock excavation. Thus, additional study of this realignment was not warranted.

Anchorage Modification - Delaware River, Philadelphia to the Sea. Initial considerations included the possibility of modifying anchorages between Philadelphia and the Sea. A series of six Federally authorized anchorages and 13 naturally deep, U.S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and the Delaware Bay. Included are

general and special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages are generally used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space for favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, is most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U.S. Coast Guard records indicated that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concluded that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage should be modified to provide a compatible depth. Modifications to the Mantua Creek and an additional portion of the Marcus Hook Anchorage would be needed to continue safe vessel docking practices. Thus, additional study of anchorage modifications was warranted.

No Action. Initial considerations included the possibility of no action or modifications of the Delaware River navigation channel. The no action plan would entail continued maintenance of the currently authorized Delaware River, Philadelphia to the sea, Federal navigation channel (Figures 2 and 3). This project, last modified in 1958, provides a 40 foot deep mlw channel from Allegheny Avenue in Philadelphia, Pennsylvania to deep water in Delaware Bay. Channel widths vary within the river. Through Philadelphia Harbor, an asymmetric channel is 40 feet deep and between 400 and 500 feet wide on the west side of the river, and 37 feet deep and between 500 and 600 feet wide on the east side of the river. From Philadelphia Harbor to Bombay Hook in Delaware Bay, the channel is 800 feet wide. The channel increases to 1,000 feet wide in Delaware Bay. There are 19 designated anchorages of which 13 occur in naturally deep water. The project requires average annual maintenance dredging of 5,400,000 cubic yards of material. Dredged material is placed in seven Federally operated, upland dredged material disposal areas located along the New Jersey side of the river, and an open water site located in Delaware Bay.

While separate inbound and outbound lanes are provided with the existing channel, vessels generally navigate the center of the channel, except when in a passing situation. Vessels with drafts up to 37 feet can navigate the channel without consideration of tidal stage. Vessels with drafts between 37 and 40 feet navigate the channel by using the tides. Inbound vessels generally leave the pilot transfer area at the mouth of Delaware Bay 2.5 hours before high tide, and travel upriver at speeds between eight and 13 knots. This provides sufficient time for vessels to pass the rock ledge at Marcus Hook with the water level at least three feet above local mean low water. This allows a minimum of three feet underkeep clearance and provides enough time to dock before the current changes after high tide. Overall trip time for inbound vessels is 7.5 hours. Loaded outbound vessels leave Philadelphia two hours before high tide to clear Marcus Hook with maximum clearance. By the time low tide occurs, the ship has traveled to naturally deep water in the upper bay. Ships then wait for a rising tide to finish the trip, taking a total of 10.5 hours. Vessel speeds are adjusted to limit squat to about two feet on inbound trips and one foot on outbound trips.

Without implementation of the proposed improvements to the Delaware River Philadelphia to the sea navigation channel, the maximum draft of vessels, transiting the river would be limited to the draft now accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of tankers and dry bulk carriers are currently forced to employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic viability of the operators. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterbound commerce with other East Coast ports. Thus, the possibility of no action was not warranted.

VERSION F

PURPOSE AND NEED

Study Authority

The Delaware River Comprehensive Navigation Study was authorized by a resolution adopted by the United States House of Representative, Committee on public Works, dated December 2, 1970. The study also responds to two resolutions adopted by the United States Senate, Committee on Public Works, dated March 1, 1954 and September 20, 1974. These resolutions are contained in the Introduction section of the main report.

Planning Objectives

The purpose of this planning study is to evaluate the need for a and alternative methods of improving the navigation channel to accommodate commercial vessels transiting the Delaware River between Philadelphia, Pennsylvania and the mouth of the Delaware Bay (Figure 1), as well as its tributary projects that support commercial navigation. The need is based on current shipping problems resulting from delays in intermodal transfers, insufficient channel dimensions and other physical aspects affecting waterborne commerce.

Problems, Needs and Public Concerns

The major problem associated with the existing Delaware River, Philadelphia to the Sea, Federal navigation project (Figures 2 and 3) is an insufficient channel depth to accommodate bulk commodity vessels at design drafts. The commodities, which include crude oil, coal and iron ore, are currently shipped in partially loaded vessels due to draft restrictions.

Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude and refined oil products are the highest volume commodity in United States freight trade and account for the overwhelming majority of tonnage moved in the Delaware River. The refineries located along the Delaware River account for a significant portion of the refinery capacity of the United States and provide petroleum products throughout the mid-Atlantic states. A large amount of the crude oil that comes to the Delaware River facilities is lightered. Lightering is the transfer of cargo from a large, deep-draft vessel to a smaller vessel or barge to maximize the cargo tonnage carried over a long voyage. Vessels that require a depth greater than 40 feet must transfer a portion of their cargo in Delaware Bay before they can travel upriver. In addition, many of the coal vessels and iron ore vessels are also partially loaded. Provision of a deeper channel would reduce or eliminate inefficient non-structural practices such as lightering and light loading, now employed for restricted vessels. In addition, several users are likely to utilize larger vessels if a deeper channel is provided.

A critical element in the development of any navigation study is the disposal of dredged material. approximately 5.4 million cubic yards of material for the existing 40' deep channel project are annually dredged from the Delaware River between Philadelphia and the sea. Acquisition of disposal areas for the existing channel is now solely a Federal responsibility. There are seven active upland disposal areas for the Philadelphia to the sea project. Additional dredged material disposal sites are needed to adequately handle dredged material from the existing Federal project past the year 2020. New disposal areas are also required for new construction and maintenance of a deeper channel. A secondary goal of this study is to upgrade present disposal areas and locate additional sites with sufficient capacity to handle deepening and maintenance dredging operations over the projects' full 50 year project life (2005 - 2055).

Public concerns with regard to the Delaware River and bay include protection of natural resources, specifically wetlands, fisheries and wildlife; air and water quality control; protection of municipal water supplies from salinity and chemical contamination; protection of cultural resources; and enhancement of

economic conditions within the Delaware Valley. A current concern with regard to water quality is prevention of oil spills in the river. A rash of major spills in 1989, including one in the Delaware River, has focused National attention on the safety of oil tankers and the potential for environmental damage.

ALTERNATIVES

Plans Eliminated from Future Study

The Delaware River Comprehensive Navigation Study addresses navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures include channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that are eliminated from further study.

Main Channel Deepening - Delaware River, Philadelphia to the Sea (50 foot alternative). Initial considerations of deepening the existing Delaware River navigation channel from Philadelphia to the sea include alternative depths of 42, 45 and 50 feet below mean low water (mlw). Analyses included calculations of initial dredging quantities, rock excavation, utility relocations, dredged material disposal and increased annual maintenance. Based on net benefits attributable to the three alternative depths, it will be concluded that a 50-foot mlw project would not be economically feasible under the conditions occurring at that time. As such, that alternative is eliminated from further study. Additional study of deepening up to 45 feet mlw is warranted in order to determine an optimum channel depth.

Main Channel Deepening - Delaware River, Philadelphia to Trenton. A study was conducted to determine the feasibility of deepening the existing Delaware River navigation channel from Philadelphia to Trenton (Figure 1). Alternative depths include 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river will identify the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that will benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, no further studies were conducted to consider potential modifications of the Delaware River, Philadelphia to Trenton project.

Channel Realignment at the Benjamin Franklin Bridge. The existing Delaware River navigation channel passes underneath the Benjamin Franklin Bridge close to the west abutment (Figure 2). This alignment provided a minimum vertical clearance of 129 feet mean high water (nhw), which was the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge will provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determine that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, Federal participation will not be warranted when the improvement would serve a single user firm or individual, with no additional user identified for the future. Therefore, studies of this alternative were terminated.

Channel Realignment at Marcus Hook, Pennsylvania. Study of the potential deepening of the Delaware River navigation channel between Philadelphia and the Sea includes consideration of realigning the channel through the Marcus Hook, Chester and Eddystone ranges (Figure 2). The existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side will avoid extensive rock removal, but would require significant dredging of sediment due to the shallow nature of this section of the river. Formulation of these alternatives was conducted on a least cost basis since benefits would remain constant regardless of alignment. The formulation demonstrated that channel

deepening along the existing alignment at Marcus Hook is more cost-effective than realigning the channel to avoid rock excavation. This realignment is eliminated from further study.

Anchorage Modification - Delaware River, Philadelphia to the Sea. A series of six Federally authorized anchorages and 13 naturally deep, U.S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and the Delaware Bay. Included are general and special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages will generally be used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space for favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, was most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U.S. Coast Guard records indicate that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concludes that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage will be modified to provide a compatible depth. Modifications to the Mantua Creek and an additional portion of the Marcus Hook Anchorage are needed to continue safe vessel docking practices.

No Action. The no action plan entails continued maintenance of the currently authorized Delaware River, Philadelphia to the Sea, Federal navigation channel (Figures 2 and 3). This project, last modified in 1958, provided a 40 foot deep mlw channel from Allegheny Avenue in Philadelphia, Pennsylvania to deep water in Delaware Bay. Channel widths will vary within the river. Through Philadelphia Harbor, an asymmetric channel is 40 feet deep and between 400 and 500 feet wide on the west side of the river, and 37 feet deep and between 500 and 600 feet wide on the east side of the river. From Philadelphia Harbor to Bombay Hook in Delaware Bay, the channel was 800 feet wide. The channel will increase to 1,000 feet wide in Delaware Bay. There are 19 designated anchorages of which 13 occur in naturally deep water. The project will require average annual maintenance dredging of 5,400,000 cubic yards of material. Dredged material was placed in seven Federally operated, upland dredged material disposal areas located along the New Jersey side of the river, and an open water site located in Delaware Bay.

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Without implementation of the proposed improvements to the Delaware River Philadelphia to the sea navigation channel, the maximum draft of vessels, transiting the river will be limited to the draft now accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of tankers and dry bulk carriers are currently forced to employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic

viability of the operators. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterbound commerce with other East Coast ports.

VERSION G

PURPOSE AND NEED

Study Authority

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ALTERNATIVES

Plans Eliminated from Future Study

The Delaware River Comprehensive Navigation Study addresses navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures include channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that are eliminated from further study.

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Main Channel Deepening - Delaware River, Philadelphia to Trenton. Initial considerations of deepening the existing Delaware River navigation channel included the option of deepening only from Philadelphia to Trenton (Figure 1). Alternative depths included 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river identified the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that would benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, additional study of deepening from Philadelphia to Trenton were not warranted.

Channel Realignment at the Benjamin Franklin Bridge. Initial considerations included the possibility of realigning the existing Delaware River navigation at the Benjamin Franklin Bridge. The channel now passes underneath the bridge close to the west abutment (Figure 2). This alignment provides a minimum vertical clearance of 129 feet mean high water (mhw), which is the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge would provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determined that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, because this realignment improvement would serve a single user firm or individual, with no additional user identified for the future, additional study of this alternative was not warranted.

Channel Realignment at Marcus Hook, Pennsylvania. Initial considerations included the possibility of realigning the existing Delaware River navigation channel between Philadelphia and the sea through the Marcus Hook, Chester and Eddystone ranges (Figure 2). The existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side would avoid extensive rock removal, but would require significant dredging of sediment due to the shallow nature of this section of the river. Formulation of these alternatives was conducted on a least cost basis since benefits would remain constant regardless of alignment. The formulation demonstrated that channel deepening along the

existing alignment at Marcus Hook was more cost-effective than realigning the channel to avoid rock excavation. Thus, additional study of this realignment was not warranted.

Anchorage Modification - Delaware River, Philadelphia to the Sea. Initial considerations included the possibility of modifying anchorages between Philadelphia and the Sea. A series of six Federally authorized anchorages and 13 naturally deep, U.S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and the Delaware Bay. Included are general and special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages are generally used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space for favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, is most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U.S. Coast Guard records indicated that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concluded that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage should be modified to provide a compatible depth. Modifications to the Mantua Creek and an additional portion of the Marcus Hook Anchorage would be needed to continue safe vessel docking practices. Thus, additional study of anchorage modifications was warranted.

No Action. Initial considerations also included the possibility of no action or modifications to the Delaware River navigation channel. The no action plan would entail continued maintenance of the currently authorized Delaware River, Philadelphia to the sea, Federal navigation channel (Figures 2 and 3). This project, last modified in 1958, provides a 40 foot deep mhw channel from Allegheny Avenue in Philadelphia, Pennsylvania to deep water in Delaware Bay. Channel widths vary within the river. Through Philadelphia Harbor, an asymmetric channel is 40 feet deep and between 400 and 500 feet wide on the west side of the river, and 37 feet deep and between 500 and 600 feet wide on the east side of the river. From Philadelphia Harbor to Bombay Hook in Delaware Bay, the channel is 800 feet wide. The channel increases to 1,000 feet wide in Delaware Bay. There are 19 designated anchorages of which 13 occur in naturally deep water. The project requires average annual maintenance dredging of 5,400,000 cubic yards of material. Dredged material is placed in seven Federally operated, upland dredged material disposal areas located along the New Jersey side of the river, and an open water site located in Delaware Bay.

While separate inbound and outbound lanes are provided with the existing channel, vessels generally navigate the center of the channel, except when in a passing situation. Vessels with drafts up to 37 feet can navigate the channel without consideration of tidal stage. Vessels with drafts between 37 and 40 feet navigate the channel by using the tides. Inbound vessels generally leave the pilot transfer area at the mouth of Delaware Bay 2.5 hours before high tide, and travel upriver at speeds between eight and 13 knots. This provides sufficient time for vessels to pass the rock ledge at Marcus Hook with the water level at least three feet above local mean low water. This allows a minimum of three feet underkeep clearance and provides enough time to dock before the current changes after high tide. Overall trip time for inbound vessels is 7.5 hours. Loaded outbound vessels leave Philadelphia two hours before high tide to clear Marcus Hook with maximum clearance. By the time low tide occurs, the ship has traveled to naturally deep water in the upper bay. Ships then wait for a rising tide to finish the trip, taking a total of 10.5 hours. Vessel speeds are adjusted to limit squat to about two feet on inbound trips and one foot on outbound trips.

Without implementation of the proposed improvements to the Delaware River Philadelphia to the sea navigation channel, the maximum draft of vessels, transiting the river would be limited to the draft now accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of tankers and dry bulk carriers are currently forced to

employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic viability of the operators. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterbound commerce with other East Coast ports. Thus, the possibility of no action was not warranted.

VERSION H

PURPOSE AND NEED

Study Authority

The Delaware River Comprehensive Navigation Study was authorized by a resolution adopted by the United States House of Representative, Committee on public Works, dated December 2, 1970. The study also responds to two resolutions adopted by the United States Senate, Committee on Public Works, dated March 1, 1954 and September 20, 1974. These resolutions are contained in the Introduction section of the main report.

Planning Objectives

The purpose of this planning study is to evaluate the need for a and alternative methods of improving the navigation channel to accommodate commercial vessels transiting the Delaware River between Philadelphia, Pennsylvania and the mouth of the Delaware Bay (Figure 1), as well as its tributary projects that support commercial navigation. The need is based on current shipping problems resulting from delays in intermodal transfers, insufficient channel dimensions and other physical aspects affecting waterborne commerce.

Problems, Needs and Public Concerns

The major problem associated with the existing Delaware River, Philadelphia to the Sea, Federal navigation project (Figures 2 and 3) is an insufficient channel depth to accommodate bulk commodity vessels at design drafts. The commodities, which include crude oil, coal and iron ore, are currently shipped in partially loaded vessels due to draft restrictions.

Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude and refined oil products are the highest volume commodity in United States freight trade and account for the overwhelming majority of tonnage moved in the Delaware River. The refineries located along the Delaware River account for a significant portion of the refinery capacity of the United States and provide petroleum products throughout the mid-Atlantic states. A large amount of the crude oil that comes to the Delaware River facilities is lightered. Lightering is the transfer of cargo from a large, deep-draft vessel to a smaller vessel or barge to maximize the cargo tonnage carried over a long voyage. Vessels that require a depth greater than 40 feet must transfer a portion of their cargo in Delaware Bay before they can travel upriver. In addition, many of the coal vessels and iron ore vessels are also partially loaded. Provision of a deeper channel would reduce or eliminate inefficient non-structural practices such as lightering and light loading, now employed for restricted vessels. In addition, several users are likely to utilize larger vessels if a deeper channel is provided.

A critical element in the development of any navigation study is the disposal of dredged material. Approximately 5.4 million cubic yards of material for the existing 40' deep channel project are annually dredged from the Delaware River between Philadelphia and the sea. Acquisition of disposal areas for the existing channel is now solely a Federal responsibility. There are seven active upland disposal areas for the Philadelphia to the sea project. Additional dredged material disposal sites are needed to adequately handle dredged material from the existing Federal project past the year 2020. New disposal areas are also required for new construction and maintenance of a deeper channel. A secondary goal of this study is to upgrade present disposal areas and locate additional sites with sufficient capacity to handle deepening and maintenance dredging operations over the projects' full 50 year project life (2005 - 2055).

Public concerns with regard to the Delaware River and bay include protection of natural resources, specifically wetlands, fisheries and wildlife; air and water quality control; protection of municipal water supplies from salinity and chemical contamination; protection of cultural resources; and enhancement of economic conditions within the Delaware Valley. A current concern with regard to water quality is

prevention of oil spills in the river. A rash of major spills in 1989, including one in the Delaware River, has focused National attention on the safety of oil tankers and the potential for environmental damage.

ALTERNATIVES

Plans Eliminated from Future Study

The Delaware River Comprehensive Navigation Study addresses navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures include channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that are eliminated from further study.

Main Channel Deepening - Delaware River, Philadelphia to the Sea (50 foot alternative). Initial considerations of deepening the existing Delaware River navigation channel from Philadelphia to the sea include alternative depths of 42, 45 and 50 feet below mean low water (mlw). Analyses included calculations of initial dredging quantities, rock excavation, utility relocations, dredged material disposal and increased annual maintenance. Based on net benefits attributable to the three alternative depths, it will be concluded that a 50-foot mlw project would not be economically feasible under the conditions occurring at that time. As such, that alternative is eliminated from further study. Additional study of deepening up to 45 feet mlw is warranted in order to determine an optimum channel depth.

Main Channel Deepening - Delaware River, Philadelphia to Trenton. A study was conducted to determine the feasibility of deepening the existing Delaware River navigation channel from Philadelphia to Trenton (Figure 1). Alternative depths include 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river will identify the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only user that will benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, no further studies were conducted to consider potential modifications of the Delaware River, Philadelphia to Trenton project.

Channel Realignment at the Benjamin Franklin Bridge.

The existing Delaware River navigation channel passes underneath the Benjamin Franklin Bridge close to the west abutment (Figure 2). This alignment provided a minimum vertical clearance of 129 feet mean high water (nhw), which was the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge will provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determine that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, Federal participation will not be warranted when the improvement would serve a single user firm or individual, with no additional user identified for the future. Therefore, studies of this alternative were terminated.

Channel Realignment at Marcus Hook, Pennsylvania.

Study of the potential deepening of the Delaware River navigation channel between Philadelphia and the Sea includes consideration of realigning the channel through the Marcus Hook, Chester and Eddystone ranges (Figure 2). The existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side will avoid extensive rock removal, but would require significant dredging of sediment due to the shallow nature of this section of the river. Formulation of these alternatives was conducted on a least cost basis since benefits would remain constant regardless of alignment. The formulation demonstrated that channel deepening along the existing alignment at Marcus Hook is more cost-effective than realigning the channel to avoid rock excavation. This realignment is eliminated from further study.

Anchorage Modification - Delaware River, Philadelphia to the Sea. A series of six Federally authorized anchorages and 13 naturally deep, U.S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and the Delaware Bay. Included are general and

special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages will generally be used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space for favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, was most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U.S. Coast Guard records indicate that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concludes that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage will be modified to provide a compatible depth. Modifications to the Mantua Creek and an additional portion of the Marcus Hook Anchorage are needed to continue safe vessel docking practices. No Action. The no action plan entails continued maintenance of the currently authorized Delaware River, Philadelphia to the Sea, Federal navigation channel (Figures 2 and 3). This project, last modified in 1958, provided a 40 foot deep mlw channel from Allegheny Avenue in Philadelphia, Pennsylvania to deep water in Delaware Bay. Channel widths will vary within the river. Through Philadelphia Harbor, an asymmetric channel is 40 feet deep and between 400 and 500 feet wide on the west side of the river, and 37 feet deep and between 500 and 600 feet wide on the east side of the river. From Philadelphia Harbor to Bombay Hook in Delaware Bay, the channel was 800 feet wide. The channel will increase to 1,000 feet wide in Delaware Bay. There are 19 designated anchorages of which 13 occur in naturally deep water. The project will require average annual maintenance dredging of 5,400,000 cubic yards of material. Dredged material was placed in seven Federally operated, upland dredged material disposal areas located along the New Jersey side of the river, and an open water site located in Delaware Bay.

While separate inbound and outbound lanes are provided with the existing channel, vessels generally navigate the center of the channel, except when in a passing situation. Vessels with drafts up to 37 feet can navigate the channel without consideration of tidal stage. Vessels with drafts between 37 and 40 feet navigate the channel by using the tides. Inbound vessels generally left the pilot transfer area at the mouth of Delaware Bay 2.5 hours before high tide, and traveled upriver at speeds between eight and 13 knots. This provides sufficient time for vessels to pass the rock ledge at Marcus Hook with the water level at least three feet above local mean low water. This allowed a minimum of three feet underkeep clearance and provides enough time to dock before the current changes after high tide. Overall trip time for inbound vessels is 7.5 hours. Loaded outbound vessels leave Philadelphia two hours before high tide to clear Marcus Hook with maximum clearance. By the time low tide occurs, the ship has traveled to naturally deep water in the upper bay. Ships then wait for a rising tide to finish the trip, taking a total of 10.5 hours. Vessel speeds are adjusted to limit squat to about two feet on inbound trips and one foot on outbound trips.

Without implementation of the proposed improvements to the Delaware River Philadelphia to the sea navigation channel, the maximum draft of vessels, transiting the river will be limited to the draft now accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of tankers and dry bulk carriers are currently forced to employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic viability of the operators. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterbound commerce with other East Coast ports.

VERSION A

ENVIRONMENTAL EFFECTS

Effects of Dredging on the Delaware River and Bay

The tentatively selected plan of improvement consists of deepening the inbound and outbound lanes of the Delaware River, Philadelphia to the Sea navigation channel from its existing depth of 40 feet mean low water (mlw) to 45 feet mlw. Channel widths would range from 400 feet wide at the upstream end of the project (Beckett Street Terminal) to 1,000 feet wide in Delaware Bay. The following provides a discussion of the potential dredging impacts associated with construction and maintenance of the proposed plan of improvement.

Groundwater. Dredging activities have the potential to adversely impact groundwater supplies. Dredging may increase the hydraulic connection between river water and contiguous aquifers where bottom sediments of low permeability are removed. This may increase recharge to aquifers in areas where overpumping of groundwater has induced recharge from the river. Increased recharge can degrade water quality within aquifers, if the river water contains chemical contaminants or salt. This is a concern in the vicinity of Camden, New Jersey, where extensive groundwater withdrawals have reversed groundwater flow directions and induced recharge to the aquifer system from the Delaware River. Water samples from this portion of the river have been found to contain measurable concentrations of heavy metals and organic priority pollutants (DRBC, 1988a). In addition, during periods of drought, salt water intrusion could be a concern.

A study in which data were collected on the lateral and vertical distribution of sediments within the Delaware River navigation channel between northeast Philadelphia, Pennsylvania and Wilmington, Delaware was conducted by the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers (Duran, 1986). This portion of the river was selected for study because it is the most densely populated and heavily industrialized. Below Wilmington, areas adjacent to the Delaware River are predominantly rural. Aquifer recharge from the Delaware River is not a concern in this area.

Data for the study were collected using the geophysical techniques of seismic reflection and electromagnetic conductivity, as well as by using available borehole logs, test-pit data and results from previous geophysical studies. Seismic reflection is a geophysical technique which makes use of the fact that different lithologies often have different densities and transmit sound at different velocities. This causes sound waves to reflect off of the lithologic boundaries. The graphical record of these reflections thus serves as a guide to the geologic structure below the seismic instruments. The electromagnetic conductivity method makes use of the fact that the earth acts like an electrical conductor. When an electromagnetic field is created near the current surface, an electrical current is induced within the earth. This current then produces an electromagnetic field that is proportional to the degree of electrical conductivity of the ground. Since saturate clay is a relatively good conductor, electromagnetic conductivity was used to help locate clay deposits below the channel bottom.

Data collected in this study indicate that between the Benjamin Franklin Bridge in Camden and Monds Island the Delaware River navigation channel is predominantly underlain by sand. However, several deposits of silt were located within this reach of the river. These deposits were described as: a small deposit of silt underlain by sand immediately downstream of the Benjamin Franklin Bridge; a thin, continuous layer of silt over sand between the Walt Whitman Bridge and Big Timber Creek; two smaller, less continuous layers of silt above and within channel-bottom sands in the vicinity of League Island; interbedded silt and sand between Woodbury Creek and Mantua Creek; and silt below the channel at the upstream end of Little Tinicum Island. Between Monds Island and just downstream of Oldmans Creek the Delaware River navigation channel is underlain by bedrock, or bedrock overlain with thin layers of sand, silt or clay. Between Oldmans Creek and the Delaware Memorial Bridge, thick layers of clay exist below the navigation channel. In the vicinity of the Delaware Memorial Bridge the clay is overlain by at least 20 feet of silt.

Deepening the navigation channel in areas underlain by sand, bedrock or clay would not increase the rate of aquifer recharge. Portions of the river underlain by sand are already exposed, while bedrock

and clay provide an effective barrier to infiltration. In areas where silt was encountered, removal of the fine-grained sediments between the Walt Whitman Bridge and Big Timber Creek could potentially increase the rate of recharge to the aquifer. In other areas where silt was encountered, the layers were either too thin to serve as a hydrologic barrier, or too thick to be adversely impacted by the proposed dredging plan.

According to the U.S.G.S., in the vicinity of Camden and Gloucester City, New Jersey, approximately 70 million gallons of water per day are transmitted from the Delaware River into the underlying aquifer. This is because the aquifer underlying this portion of the river is significantly exposed, and the rate of groundwater removal has lowered head pressures in the aquifer, which causes water to flow from the river into the aquifer. The U.S.G.S. has indicated that the effects of this recharge to water quality have been negligible thus far, and will probably continue without negative effects provided that the river water remains free of pollutants. The rate of aquifer recharge from the river is currently maintained by the rate of groundwater withdrawal. It is estimated that the exposed interface between the river and the aquifer is capable of permitting additional recharge into the aquifer if the rate of groundwater withdrawal was increased. While removal of the silt located between the Walt Whitman Bridge and Big Timber Creek could increase the rate of recharge, it could only happen if the rate of groundwater withdrawal exceeded the capability of the currently exposed interface to transmit additional recharge. As such, the removal of silt in this portion of the channel is not considered significant with regard to protection of groundwater quality in the area.

Hydrology

The major hydrological concern with respect to the proposed modification of the Delaware River, Philadelphia to the sea navigation channel is the potential upstream migration of saline water. Industrial and municipal water intakes located on the Delaware River in the vicinity of Philadelphia could be severely impacted as a result of salinity intrusion. Salinity intrusion becomes a major concern during periods of low river flow and drought, when water is released from various basin-wide reservoirs to maintain a minimum flow within the river. A salinity control point has been established at river mile 98 near Camden, New Jersey, with associated chloride and sodium water quality standards of 180 mg/L and 100 mg/L, respectively as a maximum 30-day average. Maintenance of these standards is considered sufficient to appropriately manage salinity levels throughout the Delaware estuary. This insures protection of water supply intakes and precludes potential damage to the biota of the estuary.

In order to evaluate the potential salinity impacts associated with modifying the river channel, a study was conducted by the Delaware River Basin Commission. This study modeled the salinity regime within the estuary for the existing 40-foot channel and deeper 45-foot channel using the hydrologic conditions that existed during the 1961-1966 drought of record, and the reservoir storage available today for flow augmentation (DRBC, 1989). The Transient Salinity Intrusion Model, (TSIM), which was developed and modified for use in the Delaware estuary by Thatcher and Harleman, was used as the simulation tool to predict estuary salinities. This modeling effort is considered a "worst case" analysis based on conservative assumptions that favor salinity increases in the estuary. For purposes of tracking salinity intrusion, the model was run to indicate the location of the maximum intrusion of the 250 mg/L isochlor described in river miles upstream of the ocean boundary of the Delaware Bay. The 30-day average at river mile 98 was also calculated as it relates to the current salinity standard of 180 mg/L of chloride in the estuary.

Results of the TSIM simulations in this study are provided in Tables 11 and 12 for both the existing 40-foot navigation channel and a 45-foot channel. The results in Table 11 indicate the movement of the river mile location of the maximum instantaneous 250 mg/L isochlor for both channels for the years 1961 through 1965. The comparative results for the two channels indicate that the greatest intrusion of chloride level using this parameter occurred in November 1965. The 250 mg/L isochlor reached river mile 97.8 with the deepened channel compared to river mile 96.5 with the existing channel. Thus, the 250 mg/L isochlor moved an additional 1.3 miles upstream as a result of deepening the channel. The largest difference between these two channels occurred in 1961, when the 250 mg/L isochlor traveled an

additional 3.0 miles upstream with a deeper channel. The maximum location of this isochlor was at river mile 91.4 as river flow was higher in 1961 than 1965.

Table 11. Location of Maximum Instantaneous Intrusion of 250 mg/L Isochlor with Existing Reservoir Regulation and 1986 Depletive Uses. (DRBC, 1989).

<u>Year</u>	Existing Channel Maximum of 250 mg/L R.M.		Deepened Channel Maximum of 250 mg/L R.M.		<u>Change in Location of Isochlor River Mile</u>
	<u>Location River Mile</u>	<u>Date of Occurrence</u>	<u>Location River Mile</u>	<u>Date of Occurrence</u>	
1961	88.4	21 Oct	91.4	01 Oct	+ 3.0
1962	88.2	27 Sep	89.7	27 Sep	+ 1.5
1963	94.7	06 Nov	95.7	06 Nov	+ 1.0
1964	96.5	19 Nov	97.7	19 Nov	+ 1.3
1965	96.5	23 Nov	97.8	23 Nov	+ 1.3

Table 12. Maximum 30-Day Average Concentration of Isochlor at River Mile 98 with Existing Reservoir Regulation and 1986 Depletive Uses. (DRBC, 1989).

<u>Year</u>	Existing Channel Avg. Max. Cl. at R.M. 98		Deepened Channel Avg. Max. Cl. at R.M. 98		<u>Change in Chloride Concentration mg/L</u>
	<u>mg/L</u>	<u>Date of Occurrence</u>	<u>mg/L</u>	<u>Date of Occurrence</u>	
1961	43	15 Nov	60	13 Nov	+ 17
1962	48	05 Oct	52	07 Oct	+ 4
1963	96	07 Nov	107	10 Nov	+ 11
1964	136	29 Nov	152	29 Nov	+ 16
1965	130	09 Oct	143	07 Oct	+ 13

The results in Table 12 indicate that the variation of the maximum 30-day average concentration of chloride at river mile 98. Again, the comparative results for the two channel depths project higher concentrations of chloride under the condition of the deepened channel. The highest chloride concentration for the deepened channel was 152 mg/L, occurring in November of 1964. This concentration was 16 mg/L higher than that projected for the existing channel. The largest difference between the two plans was 17 mg/L, occurring in November of 1961. All projected chloride concentrations were below the 180 mg/L Delaware River Basin Commission standard.

The comparative results in this study related to chloride concentrations, based on modeling the existing geometry for the 1960s drought of record project an increase in the chloride concentration due to deepening. Depending on the year of simulation, the increase of the maximum 30-day average chloride concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This modeling was a "worst case" analysis that favored salinity increase in the estuary. As such, with construction of the proposed plan, the

actual salinities at river mile 98 under the conditions that existed during the 1960s drought would probably be less than those projected for this modeling effort.

Effects of Alternative Dredged Material Disposal Plans

Based on screening analysis performed to identify suitable sites for the disposal of dredge material, three new sites have been selected for construction and maintenance of the proposed project. All or portions of these three upland sites, 170, 15D and Raccoon Island, have been previously used for dredged material disposal operations. In addition, three existing sites would be required, Reedy Point North, Reedy Point South and the Buoy 10 site located in Delaware Bay. The following provides a discussion of the potential impacts associated with use of these selected sites.

Groundwater. Disposal of dredged material has the potential to adversely impact groundwater quality if contaminated leachate reaches an underlying aquifer. Disposal of dredged material in confined upland areas is more of a concern in new disposal sites as the placement of fine grained dredged material acts as a groundwater protection blanket, effectively sealing the site as it consolidates. A successive lifts of material are placed into a site and dewatered, the ability of water to percolate through the material and into the underlying aquifer is reduced. All five upland sites selected for dredge material disposal have been used in the past. Sites 15D, Raccoon Island and Reedy Point North and South are entirely blanketed with several feet of dredged material. Approximately half of site 170 is covered with a similar amount of material.

A study analyzing the chemistry of channel sediments and groundwater samples collected from monitoring wells at existing dredge material disposal sites have not identified any problems of concern. Such testing programs will continue throughout the life of the project to detect any problems before they become significant. The disposal of dredged material at selected sites is not expected to have any adverse impacts on the quality of groundwater.

VERSION B

ENVIRONMENTAL EFFECTS

Effects of Dredging on the Delaware River and Bay

The tentatively selected plan of improvement consists of deepening the inbound and outbound lanes of the Delaware River, Philadelphia to the Sea navigation channel from its existing depth of 40 feet mean low water (mlw) to 45 feet mlw. Channel widths would range from 400 feet wide at the upstream end of the project (Beckett Street Terminal) to 1,000 feet wide in Delaware Bay. The following provides a discussion of the potential dredging impacts associated with construction and maintenance of the proposed plan of improvement.

Groundwater. Dredging activities have the potential to adversely impact groundwater supplies. Dredging may increase the hydraulic connection between river water and contiguous aquifers where bottom sediments of low permeability are removed. This may increase recharge to aquifers in areas where overpumping of groundwater has induced recharge from the river. Increased recharge can degrade water quality within aquifers, if the river water contains chemical contaminants or salt. This is a concern in the vicinity of Camden, New Jersey, where extensive groundwater withdrawals have reversed groundwater flow directions and induced recharge to the aquifer system from the Delaware River. Water samples from this portion of the river have been found to contain measurable concentrations of heavy metals and organic priority pollutants (DRBC, 1988a). In addition, during periods of drought, salt water intrusion could be a concern.

A study in which data were collected on the lateral and vertical distribution of sediments within the Delaware River navigation channel between northeast Philadelphia, Pennsylvania and Wilmington, Delaware was conducted by the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers (Duran, 1986). This portion of the river was selected for study because it is the most densely populated and heavily industrialized. Below Wilmington, areas adjacent to the Delaware River are predominantly rural. Aquifer recharge from the Delaware River is not a concern in this area.

Data for the study were collected using the geophysical techniques of seismic reflection and electromagnetic conductivity, as well as by using available borehole logs, test-pit data and results from previous geophysical studies. Seismic reflection is a geophysical technique which makes use of the fact that different lithologies often have different densities and transmit sound at different velocities. This causes sound waves to reflect off of the lithologic boundaries. The graphical record of these reflections thus serves as a guide to the geologic structure below the seismic instruments. The electromagnetic conductivity method makes use of the fact that the earth acts like an electrical conductor. When an electromagnetic field is created near the current surface, an electrical current is induced within the earth. This current then produces an electromagnetic field that is proportional to the degree of electrical conductivity of the ground. Since saturated clay is a relatively good conductor, electromagnetic conductivity was used to help locate clay deposits below the channel bottom.

Data collected in this study indicate that between the Benjamin Franklin Bridge in Camden and Monds Island the Delaware River navigation channel is predominantly underlain by sand. However, several deposits of silt were located within this reach of the river. These deposits were described as: a small deposit of silt underlain by sand immediately downstream of the Benjamin Franklin Bridge; a thin, continuous layer of silt over sand between the Walt Whitman Bridge and Big Timber Creek; two smaller, less continuous layers of silt above and within channel-bottom sands in the vicinity of League Island; interbedded silt and sand between Woodbury Creek and Mantua Creek; and silt below the channel at the upstream end of Little Tinicum Island. Between Monds Island and just downstream of Oldmans Creek the Delaware River navigation channel is underlain by bedrock, or bedrock overlain with thin layers of sand, silt or clay. Between Oldmans Creek and the Delaware Memorial Bridge, thin layers of clay exist

below the navigation channel. In the vicinity of the Delaware Memorial Bridge the clay is overlain by at least 20 feet of silt.

Deepening the navigation channel in areas underlain by sand, bedrock or clay would not increase the rate of aquifer recharge. Portions of the river underlain by sand are already exposed, while bedrock and clay provide an effective barrier to infiltration. In areas where silt was encountered, removal of the fine-grained sediments between the Walt Whitman Bridge and Big Timber Creek could potentially increase the rate of recharge to the aquifer. In other areas where silt was encountered, the layers were either too thin to serve as a hydrologic barrier, or too thick to be adversely impacted by the proposed dredging plan.

According to the U.S.G.S., in the vicinity of Camden and Gloucester City, New Jersey, approximately 70 million gallons of water per day are transmitted from the Delaware River into the underlying aquifer. This is because the aquifer underlying this portion of the river is significantly exposed, and the rate of groundwater removal has lowered head pressures in the aquifer, which causes water to flow from the river into the aquifer. The U.S.G.S. has indicated that the effects of this recharge to water quality have been negligible thus far, and will probably continue without negative effects provided that the river water remains free of pollutants. The rate of aquifer recharge from the river is currently maintained by the rate of groundwater withdrawal. It is estimated that the exposed interface between the river and the aquifer is capable of permitting additional recharge into the aquifer if the rate of groundwater withdrawal was increased. While removal of the silt located between the Walt Whitman Bridge and Big Timber Creek could increase the rate of recharge, it could only happen if the rate of groundwater withdrawal exceeded the capability of the currently exposed interface to transmit additional recharge. As such, the removal of silt in this portion of the channel is not considered significant with regard to protection of groundwater quality in the area.

Hydrology. The major hydrological concern with respect to the proposed modification of the Delaware River, Philadelphia to the sea navigation channel is the potential upstream migration of saline water. Industrial and municipal water intakes located on the Delaware River in the vicinity of Philadelphia could be severely impacted as a result of salinity intrusion. Salinity intrusion becomes a major concern during periods of low river flow and drought, when water is released from various basin-wide reservoirs to maintain a minimum flow within the river. A salinity control point has been established at river mile 98 near Camden, New Jersey, with associated chloride and sodium water quality standards of 180 mg/L and 100 mg/L, respectively as a maximum 30-day average. Maintenance of these standards is considered sufficient to appropriately manage salinity levels throughout the Delaware estuary. This insures protection of water supply intakes and precludes potential damage to the biota of the estuary.

In order to evaluate the potential salinity impacts associated with modifying the river channel, a study was conducted by the Delaware River Basin Commission. This study modeled the salinity regime within the estuary for the existing 40-foot channel and deeper 45-foot channel using the hydrologic conditions that existed during the 1961-1966 drought of record, and the reservoir storage available today for flow augmentation (DRBC, 1989). The Transient Salinity Intrusion Model, (TSIM), which was developed and modified for use in the Delaware estuary by Thatcher and Harleman, was used as the simulation tool to predict estuary salinities. This modeling effort is considered a "worst case" analysis based on conservative assumptions that favor salinity increases in the estuary. For purposes of tracking salinity intrusion, the model was run to indicate the location of the maximum intrusion of the 250 mg/L isochlor described in river miles upstream of the ocean boundary of the Delaware Bay. The 30-day average at river mile 98 was also calculated as it relates to the current salinity standard of 180 mg/L of chloride in the estuary.

Results of the TSIM simulations in this study are provided in Tables 11 and 12 for both the existing 40-foot navigation channel and a 45-foot channel. The results in Table 11 indicate the movement of the river mile location of the maximum instantaneous 250 mg/L isochlor for both channels for the years 1961 through 1965. The comparative results for the two channels indicate that the greatest intrusion of chloride level using this parameter occurred in November 1965. The 250 mg/L isochlor reached river

mile 97.8 with the deepened channel compared to river mile 96.5 with the existing channel. Thus, the 250 mg/L isochlor moved an additional 1.3 miles upstream as a result of deepening the channel. The largest difference between these two channels occurred in 1961, when the 250 mg/L isochlor traveled an additional 3.0 miles upstream with a deeper channel. The maximum location of this isochlor was at river mile 91.4 as river flow was higher in 1961 than 1965.

Table 11. Location of Maximum Instantaneous Intrusion of 250 mg/L Isochlor with Existing Reservoir Regulation and 1986 Depletive Uses. (DRBC, 1989).

<u>Year</u>	<u>Existing Channel</u> Maximum of 250 mg/L R.M.		<u>Deepened Channel</u> Maximum of 250 mg/L R.M.		<u>Change in</u> <u>Location of</u> <u>Isochlor River</u> <u>Mile</u>
	<u>Location River</u> <u>Mile</u>	<u>Date of</u> <u>Occurrence</u>	<u>Location River</u> <u>Mile</u>	<u>Date of</u> <u>Occurrence</u>	
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1964	96.5	19 Nov	97.7	19 Nov	+ 1.3
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Table 12. Maximum 30-Day Average Concentration of Isochlor at River Mile 98 with Existing Reservoir Regulation and 1986 Depletive Uses, (DRBC, 1989).

<u>Year</u>	<u>Existing Channel</u> Avg. Max. Cl. at R.M. 98		<u>Deepened Channel</u> Avg. Max. Cl. at R.M. 98		<u>Change in</u> <u>Chloride</u> <u>Concentration</u> <u>mg/L</u>
	<u>mg/L</u>	<u>Date of</u> <u>Occurrence</u>	<u>mg/L</u>	<u>Date of</u> <u>Occurrence</u>	
1961	43	15 Nov	60	13 Nov	+ 17
1962	48	05 Oct	52	07 Oct	+ 4
1963	96	07 Nov	107	10 Nov	+ 11
1964	136	29 Nov	152	29 Nov	+ 16
1965	130	09 Oct	143	07 Oct	+ 13

The results in Table 12 indicate that the variation of the maximum 30-day average concentration of chloride at river mile 98. Again, the comparative results for the two channel depths project higher concentrations of chloride under the condition of the deepened channel. The highest chloride concentration for the deepened channel was 152 mg/L, occurring in November of 1964. This concentration was 16 mg/L higher than that projected for the existing channel. The largest difference between the two plans was 17 mg/L, occurring in November of 1961. All projected chloride concentrations were below the 180 mg/L Delaware River Basin Commission standard.

The comparative results in this study related to chloride concentrations, based on modeling the existing geometry for the 1960s drought of record project an increase in the chloride concentration due to

deepening. Depending on the year of simulation, the increase of the maximum 30-day average chloride concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This modeling was a "worst case" analysis that favored salinity increase in the estuary. As such, with construction of the proposed plan, the actual salinities at river mile 98 under the conditions that existed during the 1960s drought would probably be less than those projected for this modeling effort.

Effects of Alternative Dredged Material Disposal Plans

Based on screening analysis performed to identify suitable sites for the disposal of dredge material, three new sites have been selected for construction and maintenance of the proposed project. All or portions of these three upland sites, 170, 15D and Raccoon Island, have been previously used for dredged material disposal operations. In addition, three existing sites would be required, Reedy Point North, Reedy Point South and the Buoy 10 site located in Delaware Bay. The following provides a discussion of the potential impacts associated with use of these selected sites.

Groundwater. Disposal of dredged material has the potential to adversely impact groundwater quality if contaminated leachate reaches an underlying aquifer. Disposal of dredged material in confined upland areas is more of a concern in new disposal sites as the placement of fine grained dredged material acts as a groundwater protection blanket, effectively sealing the site as it consolidates. As successive lifts of material are placed into a site and dewatered, the ability of water to percolate through the material and into the underlying aquifer is reduced. All five upland sites selected for dredge material disposal have been used in the past. Sites 15D, Raccoon Island and Reedy Point North and South are entirely blanketed with several feet of dredged material. Approximately half of site 170 is covered with a similar amount of material.

A study analyzing the chemistry of channel sediments and groundwater samples collected from monitoring wells at existing dredge material disposal sites have not identified any problems of concern. Such testing programs will continue throughout the life of the project to detect any problems before they become significant. The disposal of dredged material at selected sites is not expected to have any adverse impacts on the quality of groundwater.

VERSION C

ENVIRONMENTAL EFFECTS

Effects of Dredging on the Delaware River and Bay

The tentatively selected plan of improvement consists of deepening the inbound and outbound lanes of the Delaware River, Philadelphia to the Sea navigation channel from its existing depth of 40 feet mean low water (mlw) to 45 feet mlw. Channel widths would range from 400 feet wide at the upstream end of the project (Beckett Street Terminal) to 1,000 feet wide in Delaware Bay. The following provides a discussion of the potential dredging impacts associated with construction and maintenance of the proposed plan of improvement.

Groundwater. Dredging activities have the potential to adversely impact groundwater supplies. Dredging may increase the hydraulic connection between river water and contiguous aquifers where bottom sediments of low permeability were removed. This may increase recharge to aquifers in areas where overpumping of groundwater had induced recharge from the river. Increased recharge can degrade water quality within aquifers, if the river water contains chemical contaminants or salt. This was a concern in the vicinity of Camden, New Jersey, where extensive groundwater withdrawals have reversed groundwater flow directions and induced recharge to the aquifer system from the Delaware River. Water samples from this portion of the river had been found to contain measurable concentrations of heavy metals and organic priority pollutants (DRBC, 1988a). In addition, during periods of drought, salt water intrusion could be a concern.

A study in which data were collected on the lateral and vertical distribution of sediments within the Delaware River navigation channel between northeast Philadelphia, Pennsylvania and Wilmington, Delaware was conducted by the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers (Duran, 1986). This portion of the river was selected for study because it was the most densely populated and heavily industrialized. Below Wilmington, areas adjacent to the Delaware River will be predominantly rural. Aquifer recharge from the Delaware River is not a concern in this area.

Data for the study are collected using the geophysical techniques of seismic reflection and electromagnetic conductivity, as well as by using available borehole logs, test-pit data and results from previous geophysical studies. Seismic reflection is a geophysical technique which makes use of the fact that different lithologies often have different densities and transmit sound at different velocities. This causes sound waves to reflect off of the lithologic boundaries. The graphical record of these reflections thus will serve as a guide to the geologic structure below the seismic instruments. The electromagnetic conductivity method makes use of the fact that the earth acts like an electrical conductor. When an electromagnetic field is created near the current surface, an electrical current is induced within the earth. This current then produced an electromagnetic field that is proportional to the degree of electrical conductivity of the ground. Since saturate clay will be a relatively good conductor, electromagnetic conductivity was used to help locate clay deposits below the channel bottom.

Data collected in the study indicated that between the Benjamin Franklin Bridge in Camden and Monds Island the Delaware River navigation channel was predominantly underlain by sand. However, several deposits of silt are located within this reach of the river. These deposits were described as: a small deposit of silt underlain by sand immediately downstream of the Benjamin Franklin Bridge; a thin, continuous layer of silt over sand between the Walt Whitman Bridge and Big Timber Creek; two smaller, less continuous layers of silt above and within channel-bottom sands in the vicinity of League Island; interbedded silt and sand between Woodbury Creek and Mantua Creek; and silt below the channel at the upstream end of Little Tinicum Island. Between Monds Island and just downstream of Oldmans Creek, the Delaware River navigation channel is underlain by bedrock, or bedrock overlain with thin layers of sand, silt or clay. Between Oldmans creek and the Delaware memorial Bridge, thin layers of clay existed

below the navigation channel. In the vicinity of the Delaware Memorial Bridge, the clay will be overlain by at least 20 feet of silt.

Deepening the navigation channel in areas underlain by sand, bedrock or clay will not increase the rate of aquifer recharge. Portions of the river underlain by sand are already exposed, while bedrock and clay provide an effective barrier to infiltration. In areas where silt was encountered, removal of the fine-grained sediments between the Walt Whitman Bridge and Big Timber Creek potentially increases the rate of recharge to the aquifer. In other areas where silt was encountered, the layers are either too thin to serve as a hydrologic barrier, or too thick to be adversely impacted by the proposed dredging plan.

According to the U.S.G.S., in the vicinity of Camden and Gloucester City, New Jersey, approximately 70 million gallons of water per day will be transmitted from the Delaware River into the underlying aquifer. This is because the aquifer underlying this portion of the river is significantly exposed, and the rate of groundwater removal has lowered head pressures in the aquifer, which will cause water to flow from the river into the aquifer. The U.S.G.S. had indicated that the effects of this recharge to water quality have been negligible thus far, and will probably continue without negative effects provided that the river water remains free of pollutants. The rate of aquifer recharge from the river is currently maintained by the rate of groundwater withdrawal. It was estimated that the exposed interface between the river and the aquifer is capable of permitting additional recharge into the aquifer if the rate of groundwater withdrawal will be increased. While removal of the silt located between the Walt Whitman Bridge and Big Timber Creek could increase the rate of recharge, it could only happen if the rate of groundwater withdrawal exceeded the capability of the currently exposed interface to transmit additional recharge. As such, the removal of silt in this portion of the channel was not considered significant with regard to protection of groundwater quality in the area.

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Results of the TSIM simulations are provided in Tables 11 and 12 for both the existing 40-foot navigation channel and a 45-foot channel. The results in Table 11 indicate the movement of the river mile location of the maximum instantaneous 250 mg/L isochlor for both channels for the years 1961 through 1965. The comparative results for the two channel depths indicate that the greatest intrusion of chloride level using this parameter occurred in November 1965. The 250 mg/L isochlor reached river mile 97.8 with the deepened channel compared to river mile 96.5 with the existing channel. Thus, the 250 mg/L isochlor

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<u>Year</u>	Existing Channel Maximum of 250 mg/L R.M.		Deepened Channel Maximum of 250 mg/L R.M.		<u>Change in Location of Isochlor River Mile</u>
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The comparative results in this study related to chloride concentrations, based on modeling the existing geometry for the 1960s drought of record, will indicate that there is an increase in the chloride concentration due to deepening. Depending on the year of simulation, the increase of the maximum 30-

day average chloride concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This modeling was a "worst case" analysis that favored salinity increase in the estuary. As such, with construction of the proposed plan, the actual salinities at river mile 98 under the conditions that existed during the 1960s drought would probably be less than those projected for this modeling effort.

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VERSION D ENVIRONMENTAL EFFECTS

Effects of Dredging on the Delaware River and Bay

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navigation channel. In the vicinity of the Delaware Memorial Bridge the clay is overlain by at least 20 feet of silt.

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In order to evaluate the potential salinity impacts associated with modifying the river channel, the Delaware River Basin Commission was contracted to model the salinity regime within the estuary for the existing 40-foot channel and deeper 45-foot channel using the hydrologic conditions that existed during the 1961-1966 drought of record, and the reservoir storage available today for flow augmentation (DRBC, 1989). The Transient Salinity Intrusion Model, (TSIM), which was developed and modified for use in the Delaware estuary by Thatcher and Harleman, was used as the simulation tool to predict estuary salinities. This modeling effort is considered a "worst case" analysis based on conservative assumptions that favor salinity increases in the estuary. For purposes of tracking salinity intrusion, the model was run to indicate the location of the maximum intrusion of the 250 mg/L isochlor described in river miles upstream of the ocean boundary of the Delaware Bay. The 30-day average at river mile 98 was also calculated as it relates to the current salinity standard of 180 mg/L of chloride in the estuary.

Results of the TSIM simulations are provided in Tables 11 and 12 for both the existing 40-foot navigation channel and a 45-foot channel. Table 11 indicates the movement of the river mile location of the maximum instantaneous 250 mg/L isochlor for both channels for the years 1961 through 1965. This comparison indicates that the greatest intrusion of chloride level using this parameter occurred in November 1965. The 250 mg/L isochlor reached river mile 97.8 with the deepened channel compared to river mile 96.5 with the existing channel. Thus, the 250 mg/L isochlor moved an additional 1.3 miles

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The resulting chloride concentrations based on modeling the existing geometry for the 1960s drought of record, with and without inclusion of a 5-foot channel deepening, indicate that there is an increase in the chloride concentration due to deepening. Depending on the year of simulation, the increase of the maximum 30-day average chloride concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This

modeling was a "worst case" analysis that favored salinity increase in the estuary. As such, with construction of the proposed plan, the actual salinities at river mile 98 under the conditions that existed during the 1960s drought would probably be less than those projected for this modeling effort.

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Groundwater. Impacts to groundwater quality can result from the disposal of dredged material in confined upland areas if contaminated leachate reaches an underlying aquifer. This is more of a concern in new disposal sites as the placement of fine grained dredged material acts as a groundwater protection blanket, effectively sealing the site as it consolidates. As successive lifts of material are placed into a site and dewatered, the ability of water to percolate through the material and into the underlying aquifer is reduced. All five upland sites selected for dredge material disposal have been used in the past. Sites 15D, Raccoon Island and Reedy Point North and South are entirely blanketed with several feet of dredged material. Approximately half of site 170 is covered with a similar amount of material.

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VERSION E

ENVIRONMENTAL EFFECTS

Effects of Dredging on the Delaware River and Bay

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Deepening the navigation channel in areas underlain by sand, bedrock or clay would not increase the rate of aquifer recharge. Portions of the river underlain by sand are already exposed, while bedrock and clay provide an effective barrier to infiltration. In areas where silt was encountered, removal of the fine-grained sediments between the Walt Whitman Bridge and Big Timber Creek could potentially increase the rate of recharge to the aquifer. In other areas where silt was encountered, the layers were either too thin to serve as a hydrologic barrier, or too thick to be adversely impacted by the proposed dredging plan.

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Hydrology

The major hydrological concern with respect to the proposed modification of the Delaware River, Philadelphia to the sea navigation channel is the potential upstream migration of saline water. Industrial and municipal water intakes located on the Delaware River in the vicinity of Philadelphia could be severely impacted as a result of salinity intrusion. Salinity intrusion becomes a major concern during periods of low river flow and drought, when water is released from various basin-wide reservoirs to maintain a minimum flow within the river. A salinity control point has been established at river mile 98 near Camden, New Jersey, with associated chloride and sodium water quality standards of 180 mg/L and 100 mg/L, respectively as a maximum 30-day average. Maintenance of these standards is considered sufficient to appropriately manage salinity levels throughout the Delaware estuary. This insures protection of water supply intakes and precludes potential damage to the biota of the estuary.

In order to evaluate the potential salinity impacts associated with modifying the river channel, a study was conducted by the Delaware River Basin Commission. This study modeled the salinity regime within the estuary for the existing 40-foot channel and deeper 45-foot channel using the hydrologic conditions that existed during the 1961-1966 drought of record, and the reservoir storage available today for flow augmentation (DRBC, 1989). The Transient Salinity Intrusion Model, (TSIM), which was developed and modified for use in the Delaware estuary by Thatcher and Harleman, was used as the simulation tool to predict estuary salinities. This modeling effort is considered a "worst case" analysis based on conservative assumptions that favor salinity increases in the estuary. For purposes of tracking salinity intrusion, the model was run to indicate the location of the maximum intrusion of the 250 mg/L isochlor described in river miles upstream of the ocean boundary of the Delaware Bay. The 30-day average at river mile 98 was also calculated as it relates to the current salinity standard of 180 mg/L of chloride in the estuary.

Results of the TSIM simulations are provided in Tables 11 and 12 for both the existing 40-foot navigation channel and a 45-foot channel. The results in Table 11 indicate the movement of the river mile location of the maximum instantaneous 250 mg/L isochlor for both channels for the years 1961 through 1965. The comparative results for the two channel depths indicate that the greatest intrusion of chloride level using this parameter occurred in November 1965. The 250 mg/L isochlor reached river mile 97.8 with the deepened channel compared to river mile 96.5 with the existing channel. Thus, the 250 mg/L isochlor

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1963	96	07 Nov	107	10 Nov	+ 11
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The results in Table 12 indicate that the variation of the maximum 30-day average concentration of chloride at river mile 98. Again, the comparative results for the two channel depths project higher concentrations of chloride under the condition of the deepened channel. The highest chloride concentration for the deepened channel was 152 mg/L, occurring in November of 1964. This concentration was 16 mg/L higher than that projected for the existing channel. The largest difference between these two channels was 17 mg/L, occurring in November of 1961. All projected chloride concentrations were below the 180 mg/L Delaware River Basin Commission standard.

The comparative results in this study related to chloride concentrations, based on modeling the existing geometry for the 1960s drought of record, project an increase in the chloride concentration due to deepening. Depending on the year of simulation, the increase of the maximum 30-day average chloride

concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This modeling was a "worst case" analysis that favored salinity increase in the estuary. As such, with construction of the proposed plan, the actual salinities at river mile 98 under the conditions that existed during the 1960s drought would probably be less than those projected for this modeling effort.

Effects of Alternative Dredged Material Disposal Plans

Based on screening analysis performed to identify suitable sites for the disposal of dredge material, three new sites have been selected for construction and maintenance of the proposed project. All or portions of these three upland sites, 170, 15D and Raccoon Island, have been previously used for dredged material disposal operations. In addition, three existing sites would be required, Reedy Point North, Reedy Point South and the Buoy 10 site located in Delaware Bay. The following provides a discussion of the potential impacts associated with use of these selected sites.

Groundwater. Disposal of dredged material has the potential to adversely impact groundwater quality if contaminated leachate reaches an underlying aquifer. Disposal of dredged material in confined upland areas is more of a concern in new disposal sites as the placement of fine grained dredged material acts as a groundwater protection blanket, effectively sealing the site as it consolidates. As successive lifts of material are placed into a site and dewatered, the ability of water to percolate through the material and into the underlying aquifer is reduced. All five upland sites selected for dredge material disposal have been used in the past. Sites 15D, Raccoon Island and Reedy Point North and South are entirely blanketed with several feet of dredged material. Approximately half of site 170 is covered with a similar amount of material.

A study analyzing the chemistry of channel sediments and groundwater samples collected from monitoring wells at existing dredge material disposal sites has not identified any problems of concern. Such testing programs will continue throughout the life of the project to detect any problems before they become significant. The disposal of dredged material at selected sites is not expected to have any adverse impacts on the quality of groundwater.

VERSION F ENVIRONMENTAL EFFECTS

Effects of Dredging on the Delaware River and Bay

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The resulting chloride concentrations, based on modeling the existing geometry for the 1960s drought of record, with and without inclusion of a 5-foot channel deepening, will indicate that there is an increase in the chloride concentration due to deepening. Depending on the year of simulation, the increase of the maximum 30-day average chloride concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This

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VERSION G

ENVIRONMENTAL EFFECTS

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Table 12. Maximum 30-Day Average Concentration of Isochlor at River Mile 98 with Existing Reservoir Regulation and 1986 Depletive Uses. (DRBC, 1989).

	Existing Channel Avg. Max. Cl. at R.M. 98		Deepened Channel Avg. Max. Cl. at R.M. 98		
<u>Year</u>	<u>mg/L</u>	<u>Date of Occurrence</u>	<u>mg/L</u>	<u>Date of Occurrence</u>	<u>Change in Chloride Concentration mg/L</u>
1961	43	15 Nov	60	13 Nov	+ 17
1962	48	05 Oct	52	07 Oct	+ 4
1963	96	07 Nov	107	10 Nov	+ 11
1964	136	29 Nov	152	29 Nov	+ 16
1965	130	09 Oct	143	07 Oct	+ 13

The results in Table 12 indicate that the variation of the maximum 30-day average concentration of chloride at river mile 98. Again, the comparative results for the two channel depths project higher concentrations of chloride under the condition of the deepened channel. The highest chloride concentration for the deepened channel was 152 mg/L, occurring in November of 1964. This concentration was 16 mg/L higher than that projected for the existing channel. The largest difference between these two channels was 17 mg/L, occurring in November of 1961. All projected chloride concentrations were below the 180 mg/L Delaware River Basin Commission standard.

The comparative results in this study related to chloride concentrations, based on modeling the existing geometry for the 1960s drought of record, project an increase in the chloride concentration due to deepening. Depending on the year of simulation, the increase of the maximum 30-day average chloride

concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This modeling was a "worst case" analysis that favored salinity increase in the estuary. As such, with construction of the proposed plan, the actual salinities at river mile 98 under the conditions that existed during the 1960s drought would probably be less than those projected for this modeling effort.

Effects of Alternative Dredged Material Disposal Plans

Based on screening analysis performed to identify suitable sites for the disposal of dredge material, three new sites have been selected for construction and maintenance of the proposed project. All or portions of these three upland sites, 170, 15D and Raccoon Island, have been previously used for dredged material disposal operations. In addition, three existing sites would be required, Reedy Point North, Reedy Point South and the Buoy 10 site located in Delaware Bay. The following provides a discussion of the potential impacts associated with use of these selected sites.

Groundwater. Disposal of dredged material has the potential to adversely impact groundwater quality if contaminated leachate reaches an underlying aquifer. Disposal of dredged material in confined upland areas is more of a concern in new disposal sites as the placement of fine grained dredged material acts as a groundwater protection blanket, effectively sealing the site as it consolidates. As successive lifts of material are placed into a site and dewatered, the ability of water to percolate through the material and into the underlying aquifer is reduced. All five upland sites selected for dredge material disposal have been used in the past. Sites 15D, Raccoon Island and Reedy Point North and South are entirely blanketed with several feet of dredged material. Approximately half of site 170 is covered with a similar amount of material.

A study analyzing the chemistry of channel sediments and groundwater samples collected from monitoring wells at existing dredge material disposal sites has not identified any problems of concern. Such testing programs will continue throughout the life of the project to detect any problems before they become significant. The disposal of dredged material at selected sites is not expected to have any adverse impacts on the quality of groundwater.

VERSION H

ENVIRONMENTAL EFFECTS

Effects of Dredging on the Delaware River and Bay

The tentatively selected plan of improvement consists of deepening the inbound and outbound lanes of the Delaware River, Philadelphia to the Sea navigation channel from its existing depth of 40 feet mean low water (mlw) to 45 feet mlw. Channel widths would range from 400 feet wide at the upstream end of the project (Beckett Street Terminal) to 1,000 feet wide in Delaware Bay. The following provides a discussion of the potential dredging impacts associated with construction and maintenance of the proposed plan of improvement.

Groundwater. Dredging activities have the potential to adversely impact groundwater supplies. Dredging may increase the hydraulic connection between river water and contiguous aquifers where bottom sediments of low permeability were removed. This may increase recharge to aquifers in areas where overpumping of groundwater had induced recharge from the river. Increased recharge can degrade water quality within aquifers, if the river water contains chemical contaminants or salt. This was a concern in the vicinity of Camden, New Jersey, where extensive groundwater withdrawals have reversed groundwater flow directions and induced recharge to the aquifer system from the Delaware River. Water samples from this portion of the river had been found to contain measurable concentrations of heavy metals and organic priority pollutants (DRBC, 1988a). In addition, during periods of drought, salt water intrusion could be a concern.

The U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, collected data on the lateral and vertical distribution of sediments within the Delaware River navigation channel between northeast Philadelphia, Pennsylvania and Wilmington, Delaware (Duran, 1986). This portion of the river was selected for study because it was the most densely populated and heavily industrialized. Below Wilmington, areas adjacent to the Delaware River will be predominantly rural. Aquifer recharge from the Delaware River is not a concern in this area.

Data for the study are collected using the geophysical techniques of seismic reflection and electromagnetic conductivity, as well as by using available borehole logs, test-pit data and results from previous geophysical studies. Seismic reflection is a geophysical technique which makes use of the fact that different lithologies often have different densities and transmit sound at different velocities. This causes sound waves to reflect off of the lithologic boundaries. The graphical record of these reflections thus will serve as a guide to the geologic structure below the seismic instruments. The electromagnetic conductivity method makes use of the fact that the earth acts like an electrical conductor. When an electromagnetic field is created near the current surface, an electrical current is induced within the earth. This current then produced an electromagnetic field that is proportional to the degree of electrical conductivity of the ground. Since saturate clay will be a relatively good conductor, electromagnetic conductivity was used to help locate clay deposits below the channel bottom.

Study data indicated that between the Benjamin Franklin Bridge in Camden and Monds Island the Delaware River navigation channel was predominantly underlain by sand. However, several deposits of silt are located within this reach of the river. These deposits were described as: a small deposit of silt underlain by sand immediately downstream of the Benjamin Franklin Bridge; a thin, continuous layer of silt over sand between the Walt Whitman Bridge and Big Timber Creek; two smaller, less continuous layers of silt above and within channel-bottom sands in the vicinity of League Island; interbedded silt and sand between Woodbury Creek and Mantua Creek; and silt below the channel at the upstream end of Little Tinicum Island. Between Monds Island and just downstream of Oldmans Creek, the Delaware River navigation channel is underlain by bedrock, or bedrock overlain with thin layers of sand, silt or clay. Between Oldmans creek and the Delaware memorial Bridge, thick layers of clay existed below the navigation channel. In the vicinity of the Delaware Memorial Bridge, the clay will be overlain by at least 20 feet of silt.

Deepening the navigation channel in areas underlain by sand, bedrock or clay will not increase the rate of aquifer recharge. Portions of the river underlain by sand are already exposed, while bedrock

and clay provide an effective barrier to infiltration. In areas where silt was encountered, removal of the fine-grained sediments between the Walt Whitman Bridge and Big Timber Creek potentially increases the rate of recharge to the aquifer. In other areas where silt was encountered, the layers are either too thin to serve as a hydrologic barrier, or too thick to be adversely impacted by the proposed dredging plan.

According to the U.S.G.S., in the vicinity of Camden and Gloucester City, New Jersey, approximately 70 million gallons of water per day will be transmitted from the Delaware River into the underlying aquifer. This is because the aquifer underlying this portion of the river is significantly exposed, and the rate of groundwater removal has lowered head pressures in the aquifer, which will cause water to flow from the river into the aquifer. The U.S.G.S. had indicated that the effects of this recharge to water quality have been negligible thus far, and will probably continue without negative effects provided that the river water remains free of pollutants. The rate of aquifer recharge from the river is currently maintained by the rate of groundwater withdrawal. It was estimated that the exposed interface between the river and the aquifer is capable of permitting additional recharge into the aquifer if the rate of groundwater withdrawal will be increased. While removal of the silt located between the Walt Whitman Bridge and Big Timber Creek could increase the rate of recharge, it could only happen if the rate of groundwater withdrawal exceeded the capability of the currently exposed interface to transmit additional recharge. As such, the removal of silt in this portion of the channel was not considered significant with regard to protection of groundwater quality in the area.

Hydrology

The major hydrological concern with respect to the proposed modification of the Delaware River, Philadelphia to the sea navigation channel is the potential upstream migration of saline water. Industrial and municipal water intakes located on the Delaware River in the vicinity of Philadelphia could be severely impacted as a result of salinity intrusion. Salinity intrusion becomes a major concern during periods of low river flow and drought, when water is released from various basin-wide reservoirs to maintain a minimum flow within the river. A salinity control point has been established at river mile 98 near Camden, New Jersey, with associated chloride and sodium water quality standards of 180 mg/L and 100 mg/L, respectively as a maximum 30-day average. Maintenance of these standards is considered sufficient to appropriately manage salinity levels throughout the Delaware estuary. This insures protection of water supply intakes and precludes potential damage to the biota of the estuary.

In order to evaluate the potential salinity impacts associated with modifying the river channel, the Delaware River Basin Commission was contracted to model the salinity regime within the estuary for the existing 40-foot channel and deeper 45-foot channel using the hydrologic conditions that existed during the 1961-1966 drought of record, and the reservoir storage available today for flow augmentation (DRBC, 1989). The Transient Salinity Intrusion Model, (TSIM), which was developed and modified for use in the Delaware estuary by Thatcher and Harleman, was used as the simulation tool to predict estuary salinities. This modeling effort is considered a "worst case" analysis based on conservative assumptions that favor salinity increases in the estuary. For purposes of tracking salinity intrusion, the model was run to indicate the location of the maximum intrusion of the 250 mg/L isochlor described in river miles upstream of the ocean boundary of the Delaware Bay. The 30-day average at river mile 98 was also calculated as it relates to the current salinity standard of 180 mg/L of chloride in the estuary.

Results of the TSIM simulations are provided in Tables 11 and 12 for both the existing 40-foot navigation channel and a 45-foot channel. Table 11 indicates the movement of the river mile location of the maximum instantaneous 250 mg/L isochlor for both channels for the years 1961 through 1965. This comparison indicates that the greatest intrusion of chloride level using this parameter occurred in November 1965. The 250 mg/L isochlor reached river mile 97.8 with the deepened channel compared to river mile 96.5 with the existing channel. Thus, the 250 mg/L isochlor moved an additional 1.3 miles upstream as a result of deepening the channel. The largest difference between these two channels occurred in 1961, when the 250 mg/L isochlor traveled an additional 3.0 miles upstream with a deeper channel. The maximum location of this isochlor was at river mile 91.4 as river flow was higher in 1961 than 1965.

Table 11. Location of Maximum Instantaneous Intrusion of 250 mg/L Isochlor with Existing Reservoir Regulation and 1986 Depletive Uses. (DRBC, 1989).

<u>Year</u>	Existing Channel Maximum of 250 mg/L R.M.		Deepened Channel Maximum of 250 mg/L R.M.		<u>Change in Location of Isochlor River Mile</u>
	<u>Location River Mile</u>	<u>Date of Occurrence</u>	<u>Location River Mile</u>	<u>Date of Occurrence</u>	
1961	88.4	21 Oct	91.4	01 Oct	+ 3.0
1962	88.2	27 Sep	89.7	27 Sep	+ 1.5
1963	94.7	06 Nov	95.7	06 Nov	+ 1.0
1964	96.5	19 Nov	97.7	19 Nov	+ 1.3
1965	96.5	23 Nov	97.8	23 Nov	+ 1.3

Table 12. Maximum 30-Day Average Concentration of Isochlor at River Mile 98 with Existing Reservoir Regulation and 1986 Depletive Uses, (DRBC, 1989).

<u>Year</u>	Existing Channel Avg. Max. Cl. at R.M. 98		Deepened Channel Avg. Max. Cl. at R.M. 98		<u>Change in Chloride Concentration mg/L</u>
	<u>mg/L</u>	<u>Date of Occurrence</u>	<u>mg/L</u>	<u>Date of Occurrence</u>	
1961	43	15 Nov	60	13 Nov	+ 17
1962	48	05 Oct	52	07 Oct	+ 4
1963	96	07 Nov	107	10 Nov	+ 11
1964	136	29 Nov	152	29 Nov	+ 16
1965	130	09 Oct	143	07 Oct	+ 13

Table 12 indicated that the variation of the maximum 30-day average concentration of chloride at river mile 98. Again, the higher concentrations of chloride are projected under the condition of the deepened channel. The highest chloride concentration for the deepened channel was 152 mg/L, occurring in November of 1964. This concentration was 16 mg/L higher than that projected for the existing channel. The largest difference between the two plans is 17 mg/L, occurring in November of 1961. All projected chloride concentrations were below the 180 mg/L Delaware River Basin Commission standard.

The resulting chloride concentrations, based on modeling the existing geometry for the 1960s drought of record, with and without inclusion of a 5-foot channel deepening, will indicate that there is an increase in the chloride concentration due to deepening. Depending on the year of simulation, the increase of the maximum 30-day average chloride concentration at river mile 98 ranged from 4 mg/L to 17 mg/L. This modeling was a "worst case" analysis that favored salinity increase in the estuary. As such, with construction of the proposed plan, the actual salinities at river mile 98 under the conditions that existed during the 1960s drought would probably be less than those projected for this modeling effort.

Effects of Alternative Dredged Material Disposal Plans

Based on screening analysis performed to identify suitable sites for the disposal of dredge material, three new sites have been selected for construction and maintenance of the proposed project. All or portions of these three upland sites, 170, 15D and Raccoon Island, have been previously used for dredged material disposal operations. In addition, three existing sites would be required, Reedy Point North, Reedy Point South and the Buoy 10 site located in Delaware Bay. The following provides a discussion of the potential impacts associated with use of these selected sites.

Groundwater. Impacts to groundwater quality can result from the disposal of dredged material in confined upland areas if contaminated leachate reaches an underlying aquifer. This was more of a concern in new disposal sites as the placement of fine grained dredged material acts as a groundwater protection blanket, effectively sealing the site as it consolidates. As successive lifts of material are placed into a site and dewatered, the ability of water to percolate through the material and into the underlying aquifer will be reduced. All five upland sites selected for dredge material disposal had been used in the past. Sites 15D, Raccoon Island and Reedy Point North and South were entirely blanketed with several feet of dredged material. Approximately half of site 170 is covered with a similar amount of material.

Chemical analyses of channel sediments and groundwater samples collected from monitoring wells at existing dredge material disposal sites had not identified any problems of concern. These testing programs will continue throughout the life of the project to detect any problems before they become significant. The disposal of dredged material at selected sites was not expected to have any adverse impacts on the quality of groundwater.

Appendix B: Bergstrom AFB Closing Test Versions

GENERAL INFORMATION

Appendix B contains, on the following pages, Versions G (plus all cohesion) and H (minus all cohesion) for both the Purpose and Need and Environmental Effects sections. A subset of the tested Versions is presented in this Appendix to reduce the size of the overall document.

VERSION G

PURPOSE AND NEED

Bergstrom Air Force Base, Texas, was one of the bases recommended for closure by the 1991 Defense Base Closure and Realignment Commission. The Commission's recommendations were accepted by the President and submitted to Congress on July 12, 1991. Because Congress did not disapprove the recommendations in the time given under the Defense Base Closure and Realignment Act (DBCRA) of 1990 (Public Law 101-510, Title XXIX), the recommendations have become law. Bergstrom AFB is scheduled to close in September 1993.

The US Air Force is required to comply with the National Environmental Policy Act (NEPA) in the implementation of base disposal and reuse. The Air Force will make a series of interrelated decisions concerning the disposition of base property. This Environmental Impact Statement (EIS) has been prepared to provide information on the potential impacts resulting from Air Force decisions regarding disposal and proposed reuse of the small portion of the base property within the Air Force's decision-making authority. The Federal Aviation Administration (FAA), as a cooperating agency in the preparation of this EIOS, will make decisions on their own and assist the Air Force in making related decisions concerning all Bergstrom AFB property. Several alternative reuse concepts have been studied to identify a range of potential direct and indirect environmental consequences of disposal.

After completion and consideration of this EIS, the Air Force will prepare decision documents stating what property is excess and surplus, and the terms and conditions under which the dispositions will be made. These decisions may affect the environment by influencing the nature of the property's future use. However, most of the property must be surrendered to the city of Austin to use as it sees fit. This is based on considerations included in the original land transfer documents completed when the base was established in the 1940s, whereby the City of Austin has claimed equitable interest in approximately 2,892 acres of the 3,216 acres comprising Bergstrom AFB. It has been determined that the United States, acting through the Air Force must surrender title to the land in question to the City of Austin when the base is closed. This surrender of property is subject to certain rights of the United States, such as retaining a cantonment area for the Air Force Reserve 924th Fighter Group. Air Force decisions will be made regarding the disposal of four government fee-purchased land parcels totaling 324 acres. The environmental impacts of alternative reuse scenarios for the entire base are addressed in this EIS to consider cumulative impacts on making Air Force decisions regarding disposal of the 324 acres, as well as decisions on the siting of the government-retained cantonment area for Reserve operations.

Alternatives

For the purpose of evaluating potential environmental impacts resulting from the incident reuse of the land, The Air Force has based its Proposed Action on the City of Austin's expressed interest in relocating its municipal airport to the base. The Proposed Action, therefore, is the development of a commercial air carrier airport, with construction of a new parallel 9,000-foot runway with a 6,500-foot centerline-to-centerline separation from the existing 12,250-foot primary runway at Bergstrom AFB. Acquisition of up to 917 acres of land south of the base by the city of Austin may be required. A passenger terminal building complex and other aviation support facilities would be constructed between the two runways.

With the Proposed Action, four Air Force units -- the 924th FG (including the 704th Fighter Squadron and its F-16 aircraft) < Headquarters 10th Air Force, Air Combat Command Regional Corrosion Control Facility, and Ground Combat Readiness Center -- would remain at the base. Compatible nonaviation reuses would include industrial, commercial, institutional, and recreational uses. For the Proposed Action, it was assumed that Robert Mueller Municipal Airport would be closed and converted to industrial, commercial, institutional, and residential uses.

The following alternatives to the Proposed Action are considered:

1. **Redevelopment of the base as an airport.** This airport would support only air cargo, general aviation, and military flying operations, with retention of the four Air Force units previously mentioned and development of mixed nonaviation uses. This alternative would reuse the existing runways and airfield areas. It was assumed that Robert Mueller Municipal Airport would remain open for air carrier operations with this alternative.
2. **Redevelopment of the base for nonaviation mixed uses.** The nonaviation reuses would include industrial, commercial, institutional, residential, agricultural, and recreational uses. The four Air Force units would not remain with this alternative because there would be no operational airfield. Robert Mueller Municipal Airport would remain open with this alternative.
3. **The No-Action Alternative.** This alternative would result in the United States Government retaining ownership of the four government fee-purchased land parcels after closure. Surrender of the property in which the City of Austin has claimed an equitable interest would not be developed.

Summary of Environmental Impacts of Proposed Action

Local Community

The proposed Action would result in increases on employment and population in Travis County. A total of 17,571 total direct jobs (6,656 new direct jobs) and an additional 5,284 secondary jobs would be generated by 2012. The population of Travis County is projected to increase by 6,460 because most jobs would either be filled locally or would be transferred from Robert Mueller Municipal Airport and office, industrial, and commercial centers in the Austin metropolitan area.

Land use on the base would change substantially from the current pattern of mixed use, and demolition of a number of facilities would be required. Specific changes would include construction of a new runway, a passenger terminal complex, additional aviation support facilities (including facilities for the 924th Fighter Group and Texas Air National Guard, which would be relocate from (Robert Mueller Municipal Airport), and some industrial, institutional, and commercial facilities. Reuse proposals would generally be consistent with local land use plans and policies, although local zoning may need to be changed north of the base to reflect the existence of an airport. The Proposed Action would improve use of airspace in the Austin area with closure of the Municipal Airport. Average daily traffic on local roads providing access to the base would increase substantially above closure baseline levels, by the level of service during peak hours on key roads would remain as level of service C or better (i.e., good operating conditions) if planned improvements by the Texas Department of Transportation are implemented on time, utility consumption associated with the Proposed Action would represent a relatively small increase in the total demand over closure baseline conditions, but all utility providers currently have excess capacity.

Hazardous Materials and Hazardous Waste Management

The types of hazardous materials and waste used and generated as a result of the Proposed Action are expected to be similar to those used and generated during preclosure conditions. The responsibility for managing hazardous materials and waste would shift from a single user to multiple, independent users. This may result in a reduction of service if there is no single onsite organization capable of responding to hazardous material and waste spills. The reusers would also implement pollution prevention and waste minimization strategies that have been recommended by the Environmental Protection Agency (EPA) in its *Guides to Pollution Prevention* series of publications and *Waste Minimization Opportunity Assessment Manual*. It was assumed that adequate management procedures would be imposed, as required by applicable laws and regulations, to ensure proper use and handling of hazardous materials.

Reuse activities are not expected to affect the remediation and/or closure of Installation Restoration Program (IRP) sites or Solid Waste Management Units. However, the IRP remediation schedule could result in delays in the redevelopment of some portions of the base. Existing underground storage tanks not required for reuse activities will be removed by the Air Force. All polychlorinated biphenyl (PCB) and PCB-contaminated equipment has been removed from the base except in two facilities: an aircraft lighting system vault with 15 PCB-containing capacitors and the base hospital with a large PCB transformer. The aircraft lighting system vault capacitors are hermetically sealed and will be transferred with the building to the City of Austin; the transformers in the hospital is being regularly retrofitted with non-PCB dielectric fluid to reduce the PCB concentration. It is scheduled to be certified as non-PCB in March 1994. However, it was assumed that it will be removed because this building will likely be demolished during airfield construction for the Proposed Action. Demolition and renovation of structures with asbestos-containing materials were assumed to be performed by the new owners in compliance with applicable regulations and National Emissions Standards for Hazardous Air Pollutants. Reuse of some structures on the base may require mitigation for radon levels greater than the EPA-recommended level for residential and school structures.

Natural Environment

A total of 1,815 acres would be disturbed with the Proposed Action. Of this, about 300 acres would be on land off the base that would potentially be acquired by the City of Austin. Soils on the base are not particularly susceptible to erosion, but some soil erosion is expected to occur during construction. Construction activity would change some surface drainage flows and would increase the amount of impervious surface. Groundwater supplies would not be affected. Air pollutant emissions associated with the Proposed Action would increase above baseline closure levels. However, the increases would not be large enough to cause any exceedence of federal or state ambient standards.

Aircraft noise associated with reuse of the airfield for an air carrier airport with military operations would be less than prior to base closure. Approximately 4,330 acres would be exposed to day-night noise levels (DNL) of 65 decibels (dB) or greater in 1994, increasing to about 7,830 acres by 1997 when the air carrier airport would be fully operational. Approximately 4,065 persons are estimated to reside in this area. The area exposed to DNLs of 65 dB or greater would decrease to about 5,070 acres by 2002 and 5,000 acres by 2012, when new, quieter aircraft would be used. Approximately 2,995 persons 2002 and 2,965 in 2012 are estimated to reside in the area affected by noise. This contrasts with approximately 14,720 acres exposed to noise levels greater than 65 dB with preclosure conditions. Surface traffic noise would increase along US 183 and State Highway 71 above baseline closure levels. Residences located less than 300 feet from these highways may be exposed to DNLs of 65 dB or greater.

VERSION H

PURPOSE AND NEED

Bergstrom Air Force Base, Texas, was one of the bases recommended for closure by the 1991 Defense Base Closure and Realignment Commission. The Commission's recommendations were accepted by the President and submitted to Congress on July 12, 1991. Because Congress did not disapprove the recommendations in the time given under the Defense Base Closure and Realignment Act (DBCRA) of 1990 (Public Law 101-510, Title XXIX), the recommendations have become law. Bergstrom AFB is scheduled to close in September 1993.

The US Air Force was required to comply with the National Environmental Policy Act (NEPA) in the implementation of base disposal and reuse. The Air Force made a series of interrelated decisions concerning the disposition of base property. This Environmental Impact Statement (EIS) has been prepared to provide information on the potential impacts resulting from Air Force decisions regarding disposal and proposed reuse of the small portion of the base property within the Air Force's decision-making authority. The Federal Aviation Administration (FAA), as a cooperating agency in the preparation of this EIOS, made decisions on their own and assisted the Air Force in making related decisions concerning all Bergstrom AFB property. Several alternative reuse concepts have been studied to identify the (typo) range of potential direct and indirect environmental consequences of disposal.

After completion and consideration of this EIS, the Air Force will prepare decision documents stating what property is excess and surplus, and the terms and conditions under which the dispositions will be made. These decisions may affect the environment by influencing the nature of the property's future use. However, most of the property must be surrendered to the city of Austin to use as it sees fit. This is based on considerations included in the original land transfer documents completed when the base was established in the 1940s, whereby the City of Austin has claimed equitable interest in approximately 2,892 acres of the 3,216 acres comprising Bergstrom AFB. It has been determined that the United States, acting through the Air Force must surrender title to the land in question to the City of Austin when the base is closed. This surrender of property is subject to certain rights of the United States, such as retaining a cantonment area for the Air Force Reserve 924th Fighter Group. Air Force decisions will be made regarding the disposal of four government fee-purchased land parcels totaling 324 acres. The environmental impacts of alternative reuse scenarios for the entire base are addressed in this EIS to consider cumulative impacts on making Air Force decisions regarding disposal of the 324 acres, as well as decisions on the siting of the government-retained cantonment area for Reserve operations.

Alternatives

For the purpose of evaluating potential environmental impacts resulting from the incident reuse of the land, the Air Force had based its Proposed Action on the City of Austin's expressed interest in relocating its municipal airport to the base. The Proposed Action, therefore, was the development of a commercial air carrier airport, with construction of a new parallel 9,000-foot runway with a 6,500-foot centerline-to-centerline separation from the existing 12,250-foot primary runway at Bergstrom AFB. Acquisition of up to 917 acres of land south of the base by the city of Austin was required. A passenger terminal building complex and other aviation support facilities will be constructed between the two runways.

With the Proposed Action, four Air Force units -- the 924th FG (including the 704th Fighter Squadron and its F-16 aircraft) Headquarters 10th Air Force, Air Combat Command Regional Corrosion Control Facility, and Ground Combat Readiness Center -- would remain at the base. Compatible nonaviation reuses would include industrial, commercial, institutional, and recreational uses. For the Proposed Action, it was assumed that Robert Mueller Municipal Airport would be closed and converted to industrial, commercial, institutional, and residential uses.

The following alternatives to the Proposed Action are considered:

1. Redevelopment of the base as an airport supporting only air cargo, general aviation, and military flying operations, with retention of the four Air Force units previously mentioned and development of mixed nonaviation uses. It is assumed that Robert Mueller Municipal Airport would remain open for air carrier operations with this alternative. Existing runways and airfield areas would be reused.

2. The four Air Force units will not remain with this alternative because there would be no operational airfield. Nonaviation reuse for the base which will include industrial, commercial, institutional, residential, agricultural, and recreational uses. Robert Mueller Municipal Airport would remain open with this alternative.

3. The United States Government retaining ownership of the four government fee-purchased land parcels after closure. Surrender of the property in which the City of Austin has claimed an equitable interest will not be developed. This is the No-Action alternative.

Summary of Environmental Impacts of Proposed Action

Local Community

The proposed Action would result in increases on employment and population in Travis County. A total of 17,571 total direct jobs (6,656 new direct jobs) and an additional 5,284 secondary jobs would be generated by 2012. The population of Travis County is projected to increase by 6,460 because most jobs would either be filled locally or would be transferred from Robert Mueller Municipal Airport and office, industrial, and commercial centers in the Austin metropolitan area.

Land use on the base would change substantially from the current pattern of mixed use, and demolition of a number of facilities would be required. Specific changes would include construction of a new runway, a passenger terminal complex, additional aviation support facilities (including facilities for the 924th Fighter Group and Texas Air National Guard, which would be relocate from (Robert Mueller Municipal Airport), and some industrial, institutional, and commercial facilities. Reuse proposals would generally be consistent with local land use plans and policies, although local zoning may need to be changed north of the base to reflect the existence of an airport. The Proposed Action would improve use of airspace in the Austin area with closure of the Municipal Airport. Average daily traffic on local roads providing access to the base would increase substantially above closure baseline levels, by the level of service during peak hours on key roads would remain as level of service C or better (i.e., good operating conditions) if planned improvements by the Texas Department of Transportation are implemented on time, utility consumption associated with the Proposed Action would represent a relatively small increase in the total demand over closure baseline conditions, but all utility providers currently have excess capacity.

Hazardous Materials and Hazardous Waste Management

The types of hazardous materials and waste used and generated as a result of the Proposed Action are expected to be similar to those used and generated during preclosure conditions. The responsibility for managing hazardous materials and waste would shift from a single user to multiple, independent users. This may result in a reduction of service if there is no single onsite organization capable of responding to hazardous material and waste spills. The reusers would also implement pollution prevention and waste minimization strategies that have been recommended by the Environmental Protection Agency (EPA) in its *Guides to Pollution Prevention* series of publications and *Waste Minimization Opportunity Assessment Manual*. It was assumed that adequate management procedures would be imposed, as required by applicable laws and regulations, to ensure proper use and handling of hazardous materials.

Reuse activities are not expected to affect the remediation and/or closure of Installation Restoration Program (IRP) sites or Solid Waste Management Units. However, the IRP remediation schedule could result in delays in the redevelopment of some portions of the base. Existing underground storage tanks not required for reuse activities will be removed by the Air Force. All polychlorinated biphenyl (PCB)

and PCB-contaminated equipment has been removed from the base except in two facilities: an aircraft lighting system vault with 15 PCB-containing capacitors and the base hospital with a large PCB transformer. The airfield lighting system vault capacitors are hermetically sealed and will be transferred with the building to the City of Austin; the transformers in the hospital is being regularly retrofitted with non-PCB dielectric fluid to reduce the PCB concentration. It is scheduled to be certified as non-PCB in March 1994. However, it was assumed that it will be removed because this building will likely be demolished during airfield construction for the Proposed Action. Demolition and renovation of structures with asbestos-containing materials were assumed to be performed by the new owners in compliance with applicable regulations and National Emissions Standards for Hazardous Air Pollutants. Reuse of some structures on the base may require mitigation for radon levels greater than the EPA-recommended level for residential and school structures.

Natural Environment

A total of 1,815 acres will be disturbed with the Proposed Action. Of this, about 300 acres will be on land off the base that would potentially be acquired by the City of Austin. Soils on the base were not particularly susceptible to erosion, but some soil erosion is expected to occur during construction. Construction activity will change some surface drainage flows and will increase the amount of impervious surface. Groundwater supplies would not be affected. Air pollutant emissions associated with the Proposed Action will increase above baseline closure levels. However, the increases would not be large enough to cause any exceedence of federal or state ambient standards.

Aircraft noise associated with reuse of the airfield for an air carrier airport with military operations would be less than prior to base closure. Approximately 4,330 acres would be exposed to day-night noise levels (DNL) of 65 decibels (dB) or greater in 1994, increasing to about 7,830 acres by 1997 when the air carrier airport would be fully operational. Approximately 4,065 persons are estimated to reside in this area. The area exposed to DNLs of 65 dB or greater would decrease to about 5,070 acres by 2002 and 5,000 acres by 2012, when new, quieter aircraft would be used. Approximately 2,995 persons 2002 and 2,965 in 2012 are estimated to reside in the area affected by noise. This contrasts with approximately 14,720 acres exposed to noise levels greater than 65 dB with preclosure conditions. Surface traffic noise would increase along US 183 and State Highway 71 above baseline closure levels. Residences located less than 300 feet from these highways may be exposed to DNLs of 65 dB or greater.

VERSION G ENVIRONMENTAL EFFECTS

Water Resources

Potential impacts on water resources resulting from the Proposed Actions and reuse alternatives are described in this section. Construction activities could alter soil profiles and natural drainages, which, in turn, may temporarily alter water flow patterns.

Bergstrom AFB is subject to provisions of the 1986 Suburban Watersheds Ordinance of the Land Development Code of the City of Austin. These provisions allow up to 80 percent of the land to be developed with impervious cover, and depending on the degree of development, construction of water quality ponds may be required. The amount of impervious cover for any alternative would be under 80 percent.

Proposed Action

Surface Water. with the Proposed Action, soils would be compacted during new construction and overlain by asphalt, concrete, or buildings, creating impervious surfaces that would result in increased stormwater runoff to stormwater drainage systems. Drainage patterns could be altered to divert water away from facilities and airfield pavements, including the new 9000-foot runway. Stormwater discharge (nonpoint source) from the airfield, aviation support, and industrial areas may contain fuels, oils, and other residues that could degrade surface water resources, particularly Onion Creek. In addition, nonpoint source runoff could cause high sediment loads in the drainage systems.

The amount of available surface water would not change with the Proposed Action because no surface water would be used for domestic, industrial, or recreational purposes. Currently, water is supplied by the City of Austin from surface water sources off the base. The projected increase in water use with the Proposed Action would be within the capacity of the city's water supply system.

No areas would be inundated, and the potential for flooding would not increase as a result of the Proposed Action. However, approximately 2,000 feet of the South Fork Drainage Ditch would be filled or drained with construction of the new runway. If the drainage is realigned so that it does not cross the runway but instead goes southward toward the watercourse that crosses the RPZ at the south end of the runway, the South Fork Drainage Ditch would be greatly reduced in length and water supply. If however, the drainage is maintained in its present alignment by constructing a culvert under the runway, runoff to the downstream portion of the South Fork Drainage Ditch would remain about the same. The dredging or filling of this drainage course, considered a Water of the United States, would require a Section 404 permit from the US Army Corps of Engineers. In 1992, the Air Force conducted a study to determine the quality of water that may be leaching from the adjacent landfills into the South Fork Drainage Ditch. No contaminants were found to be leaching into the ditch.

Some proposed reuses will also be subject to National Pollutant Discharge Elimination System (NPDES) permit requirements for stormwater discharges during the construction period and for the duration of airport operations. This provision is contained in the NPDES Permit Application Regulations for Stormwater Discharges issued by the EPA as a final rule on November 16, 1990.

A short headwaters segment of the northern tributary to the South Fork Drainage Ditch may also have to be filled or partially filled. The proposed runway would not cross a discrete channel but may cross a topographical low area that collects drainage water for the channel. Runoff to the tributary may be reduced by a small amount. This drainage is also considered to be a Water of the United States.

It is not likely, given the nearly flat topography of the base, that stream or rill erosion would increase with the Proposed Action. However, there is a possibility for increased sedimentation as a result of storms. This would be most likely during the time of construction and could occur anywhere on the base, particularly at the site of the proposed runway. The effect would be temporary but could cause sediment to enter watercourses.

Groundwater. With the Proposed Action, there is a potential for impacts to groundwater resources. No groundwater is withdrawn at the base, and no development of groundwater resources would occur with the Proposed Action. However, accidental releases of contaminants from facilities, including storage tanks, where hazardous substances are stored and/or used, could reach the shallow aquifer over time. This could have a significant impact on groundwater uses in the area. Cleanup of existing or potentially contaminated areas will proceed promptly under the supervision of the Texas Water Commission.

Government Fee-Purchased Land. Water resources on Parcel 2 would not be significantly affected by the Proposed Action. The drainage would be altered on the western two-thirds of the parcel as a result of regrading for the proposed runway and facilities built in the aviation support area west of the runway. The drainage now consists of slope wash into the South Fork Drainage Ditch, and there would be a minor redirection of this drainage away from the runway and aviation support facilities. There would be no impacts on water resources at any of the other three government fee-purchased parcels.

Mixed-Use Development Alternative

Surface Water. With the Mixed-Use Development Alternative, soils would be compacted during new construction and overlain by asphalt, concrete, or buildings, creating impervious surfaces that would result in increased stormwater runoff to local stormwater drainage systems. Drainage patterns could be changed to divert water away from new facilities. Stormwater discharge (nonpoint source) from industrial areas may contain fuels, oils, and other residues that could degrade surface water resources, including small tributaries that flow directly to the Colorado River from the north side of the base and to Onion Creek. In addition, there is a potential for nonpoint discharge of nitrates, pesticides, and herbicides into the watercourse west of the main runway from the area proposed for agriculture.

The amount of available surface water would not change with the Mixed-Use Development Alternative because no surface water would be used for domestic, industrial, or recreational purposes. Currently, water is supplied by the City of Austin from surface water sources off the base. The projected increase in water use with this alternative would be within the capacity of the city's water supply system.

No areas would be inundated, and the potential for flooding would not increase as a result of this alternative. It is not likely, given the nearly flat topography of the base, that stream or rill erosion would be significant. However, there is a possibility for increased sedimentation as a result of storms. This would be most likely during construction and could occur anywhere on the base. The effect would be temporary but could cause sediment to enter watercourses.

Erosion and sedimentation into the watercourse west of the main runway and into Onion Creek could occur from the agricultural uses in the southwest portion of the base. Agricultural uses may include grazing, hay cropping, or row cropping. Of these, erosion would be most likely to occur with row cropping. Nitrate runoff could occur with grazing, and herbicide and pesticide runoff could occur with row cropping. Sediments and contaminants would enter Onion Creek west of the county park and also down a tributary to Onion Creek southeast of the existing taxiway and north of the county park.

Groundwater. With the Mixed-Use Development Alternative, impacts could occur to groundwater resources from accidental releases of contaminants from facilities where hazardous substances are stored and/or used. No groundwater is withdrawn at the base, and no development of groundwater

resources would occur with this alternative. Groundwater is of poor quality in most aquifers underlying the base and is not an important source of water supply downgradient of the base.

Government Fee-Purchased Land. Minor redirection of slope wash drainage into small drainage ditches would occur in Parcel 1, north of the runways, where commercial development may occur, but would not be significant. Potential impacts resulting from agricultural and public/recreation use of Parcels 2 and 3 would include erosion and sedimentation as described previously

VERSION H

ENVIRONMENTAL EFFECTS

Water Resources

Potential impacts on water resources resulting from the Proposed Actions and reuse alternatives are described in this section. Construction activities could alter soil profiles and natural drainages, which, in turn, may temporarily alter water flow patterns.

Bergstrom AFB is subject to provisions of the 1986 Suburban Watersheds Ordinance of the Land Development Code of the City of Austin. These provisions allow up to 80 percent of the land to be developed with impervious cover, and depending on the degree of development, construction of water quality ponds may be required. The amount of impervious cover for any alternative would be under 80 percent.

Proposed Action

Surface Water. With the Proposed Action alternative, soils would be compacted during new construction and overlain by asphalt, concrete, or buildings, creating impervious surfaces that would result in increased stormwater runoff to stormwater drainage systems. Drainage patterns could be altered to divert water away from facilities and airfield pavements, including the new 9000-foot runway. Stormwater discharge (nonpoint source) from the airfield, aviation support, and industrial areas may contain fuels, oils, and other residues that could degrade surface water resources, particularly Onion Creek. In addition, nonpoint source runoff could cause high sediment loads in the drainage systems.

The amount of available surface water would not change with the Proposed Action because no surface water will be used for domestic, industrial, or recreational purposes. Currently, water is supplied by the City of Austin from surface water sources off the base. The projected increase in water use with the Proposed Action will be within the capacity of the city's water supply system.

No areas would be inundated, and the potential for flooding would not increase as a result of the Proposed Action. However, approximately 2,000 feet of the South Fork Drainage Ditch would be filled or drained with construction of the new runway. If the drainage is realigned so that it does not cross the runway but instead goes southward toward the watercourse that crosses the RPZ at the south end of the runway, the South Fork Drainage Ditch would be greatly reduced in length and water supply. If however, the drainage is maintained in its present alignment by constructing a culvert under the runway, runoff to the downstream portion of the South Fork Drainage Ditch would remain about the same. The dredging or filling of this drainage course, considered a Water of the United States, would require a Section 404 permit from the US Army Corps of Engineers. In 1992, the Air Force conducted a study to determine the quality of water that may be leaching from the adjacent landfills into the South Fork Drainage Ditch. No contaminants were found to be leaching into the ditch.

Some proposed reuses will also be subject to National Pollutant Discharge Elimination System (NPDES) permit requirements for stormwater discharges during the construction period and for the duration of airport operations. This provision is contained in the NPDES Permit Application Regulations for Stormwater Discharges issued by the EPA as a final rule on November 16, 1990.

A short headwaters segment of the northern tributary to the South Fork Drainage Ditch may also have to be filled or partially filled. The proposed runway would not cross a discrete channel but may cross a topographical low area that collects drainage water for the channel. Runoff to the tributary may be reduced by a small amount. This drainage is also considered to be a Water of the United States.

It is not likely, given the nearly flat topography of the base, that stream or rill erosion would increase with the Proposed Action. However, there is a possibility for increased sedimentation as a result of storms. This would be most likely during the time of construction and could occur anywhere on the base, particularly at the site of the proposed runway. The effect would be temporary but could cause sediment to enter watercourses.

Groundwater.

There was a potential for impacts to groundwater resources with the Proposed Action. No groundwater is withdrawn at the base, and no development of groundwater resources would occur with the Proposed Action. However, accidental releases of contaminants from facilities, including storage tanks, where hazardous substances are stored and/or used, could reach the shallow aquifer over time. This could have a significant impact on groundwater uses in the area. Cleanup of existing or potentially contaminated areas will proceed promptly under the supervision of the Texas Waste Commission.

Government Fee-Purchased Land. Water resources on Parcel 2 would not be significantly affected by the Proposed Action. The drainage would be altered on the western two-thirds of the parcel as a result of regarding for the proposed runway and facilities built in the aviation support area west of the runway. The drainage now consists of slope wash into the South Fork Drainage Ditch, and there would be a minor redirection of this drainage away from the runway and aviation support facilities. There would be no impacts on water resources at any of the other three government fee-purchased parcels.

Mixed-Use Development Alternative

Surface Water. Compaction of soils will occur during new construction involving the Mixed Use Development Alternative. The soils would be overlain by asphalt, concrete, or buildings, creating impervious surfaces that would result in increased stormwater runoff to local stormwater drainage systems. Water could be diverted away from new facilities. Fuels, oils, and other residues that could degrade surface water resources, including small tributaries that flow directly to the Colorado River from the north side of the base and to Onion Creek, may be found in stormwater discharge (nonpoint source) from industrial areas. In addition, nonpoint discharge of nitrates, pesticides, and herbicides into the watercourse west of the main runway might be found from the area proposed for agriculture.

The Mixed-Use Development Alternative would not effect the amount of available surface water because no surface water will be used for domestic, industrial, or recreational purposes. At present, the City of Austin supplies water from surface water sources off the base. This alternative will increase water usage but the increase would be within the capacity of the city's water supply system.

No areas would be inundated, and the potential for flooding will not increase as a result of this alternative. It is not likely, given the nearly flat topography of the base, that stream or rill erosion would be significant. However, there is a possibility for increased sedimentation as a result of storms. This would be most likely during construction and could occur anywhere on the base. The effect would be temporary but could cause sediment to enter watercourses.

Erosion and sedimentation into the watercourse west of the main runway and into Onion Creek could occur from the agricultural uses in the southwest portion of the base. Agricultural uses may include grazing, hay cropping, or row cropping. Of these, erosion would be most likely to occur with row cropping. Nitrate runoff could occur with grazing, and herbicide and pesticide runoff could occur with row cropping. Sediments and contaminants would enter Onion Creek west of the county park and also down a tributary to Onion Creek southeast of the existing taxiway and north of the county park.

Groundwater. The Mixed-Use Development alternative could cause impacts to groundwater resources from accidental releases of contaminants for facilities where hazardous substances are stored and/or used. The base does not withdraw groundwater, and this alternative would not include

development of groundwater resources. Groundwater is of poor quality in most aquifers underlying the base and is not an important source of water supply downgradient of the base.

Government Fee-Purchased Land.

Minor redirection of slope wash drainage into small drainage ditches would occur in Parcel 1, north of the runways, where commercial development may occur, but would not be significant. Potential impacts resulting from agricultural and public/recreation use of Parcels 2 and 3 would include erosion and sedimentation as described previously

Appendix C: Subject Time Data for each EIS Version
(in seconds)

	DELAWARE RIVER PROJECT				BERGSTROM AFB CLOSING			
	Purpose		Environmental		Purpose		Environmental	
	and Need		Effects		and Need		Effects	
subject	version	total time	version	total time	version	total time	version	total time
1	A	526	B	812	C	564	D	554
2	B	868	C	654	D	364	E	414
3	C	650	D	852	E	789	F	363
4	D	846	E	1061	F	626	G	503
5	E	945	F	689	G	407	H	591
6	F	908	G	955	H	850	A	549
7	G	1080	H	997	A	987	B	701
8	H	1010	A	1607	B	614	C	794
9	A	700	B	853	C	705	D	720
10	B	1183	C	1444	D	845	E	908
11	C	1065	D	996	E	891	F	575
12	D	1242	E	1347	F	853	G	685
13	E	1286	F	914	G	526	H	454
14	F	1395	G	1098	H	399	A	745
15	G	755	H	667	A	391	B	410
16	H	569	A	757	B	523	C	570
17	A	726	B	706	C	564	D	532
18	B	822	C	627	D	450	E	426
19	C	735	D	701	E	423	F	420
20	D	1042	E	677	F	798	G	1123
21	E	1105	F	1156	G	801	H	670
22	F	1022	G	875	H	1163	A	536
23	G	1429	H	674	A	658	B	441
24	H	863	A	1199	B	326	C	399
25	A	707	B	952	C	397	D	567
26	B	872	C	681	D	438	E	613
27	C	955	D	668	E	696	F	674
28	D	919	E	539	F	360	G	466
29	E	1447	F	1456	G	651	H	875
30	F	1077	G	719	H	911	A	801
31	G	1024	H	1122	A	684	B	541
32	H	872	A	679	B	311	C	373

REPORT DOCUMENTATION PAGE		Form Approved OMB No. 0704-0188	
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13. ABSTRACT (Maximum 200 words) The purpose of this research effort was to investigate the application of certain principles of effective communication to improve the comprehension, and ultimately the usability, of an Environmental Impact Statement (EIS). Principles from cohesion theory (an area of research describing effective design) were used to manipulate the design of select sections of two sample EISs. Each sample EIS was altered to manipulate the presence and/or absence of visual and linguistic cohesion. Subjects were required to read select versions from each section of the two sample EISs and answer four short answer questions. The dependent variables were accuracy in answering the questions (a measure of coherence), and time to complete the task (a measure of usability). Statistical analyses provided no indication of significant differences between and among the visual and linguistic cohesive elements. The underlying theory and experimental design may have been contributors to these results, but since this effort was constructed as a pilot study, there were many valuable observations made for future work in this area.			
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Appendix D: Short Answer Questions

Delaware River Project EIS

Purpose and Need Section

1. Why is the U.S. Army Corps of Engineers undertaking this navigation study of the Delaware River?
2. What project does the U.S. Army Corps of Engineers propose to do as a result of their study?
3. List the alternative projects which the U.S. Army Corps of Engineers has eliminated from further consideration.
4. What would be the consequences if no future project was planned for the Delaware River navigation channel?

Environmental Effects Section

1. What effect(s) will the U.S. Army Corp of Engineers' project have on groundwater near the Delaware River navigation channel?
2. How serious is the environmental impact if salt water travels upstream from the sea into a river like the Delaware?
3. How did the U.S. Army Corps of Engineers determine whether their project will increase the danger to the environment along the Delaware River if they complete their proposed project?
4. Will completion of the U.S. Army Corps of Engineers' proposed project increase the danger to the environment along the Delaware River if salt water travels upstream?

Bergstrom AFB Closing

Purpose and Need Section

1. What projects were considered as alternatives to the Proposed Action?
2. What is the Proposed Action?
3. Why was this particular EIS done?
4. Is soil erosion likely to occur?

Environmental Impacts Section

1. What effect will increased stormwater runoff to stormwater drainage systems have on Onion Creek?
2. How do the environmental effects concerning stormwater differ between the Proposed Alternative and the Mixed-Use Alternative?
3. What are the chances of flooding with the Mixed-Use Alternative?
4. With the Mixed-Use alternative, will contamination of groundwater pose a serious problem to the base water supply?

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Vita

Jill A. Easterly graduated from Wright State University with a Bachelor of Science degree in Human Factors Engineering in 1980. From October 1980 until April 1985, she was assigned to Armstrong Laboratories as a Research Engineer. From April 1985 until May 1993 she was assigned to the Air Force Human Resources Laboratory where she managed a major human-modeling effort. She is currently attending the Air Force Institute of Technology at Wright Patterson AFB, Ohio, as a graduate student in the Engineering and Environmental Management Program.

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